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A. A. A. S. Building, Washington 5, D. C.

The American Association for the Advancement of Science

Reservations are now being accepted for space at the

Annual Science Exhibition

To be held in connection with the 113th Meeting
of the Association

Boston, Massachusetts *December 26-31, 1946*

The Exhibition, the Association, and the affiliated societies are fortunate in meeting at Boston, which is one of the most important research centers of the United States. The large number of governmental and industrial research laboratories, as well as those of the universities and colleges in the area, insure a well-attended and highly interesting meeting.

The Exhibition will be held in the First Corps Cadet Armory and the central registration for the meetings will take place within the Exhibition Hall. Through splendid cooperation of local committees and hotels, ample hotel accommodations have been secured already. The general headquarters for the meeting will be in the Hotel Statler located diagonally across the street from the First Corps Cadet Armory.

The Annual Meeting of the Association affords commercial exhibitors an unsurpassed opportunity to show their products to scientists engaged in all branches of research. At the St. Louis Meeting held this past Spring there were scientists from 46 states and 14 foreign countries. There is every reason to believe that attendance at the Boston meeting will be larger than that at St. Louis.

Special Note to Individual Scientists

This year an increased amount of space has been allocated for the demonstration of research results. Full details have been published in *Science* (104: 98), *The Scientific Monthly* for August, 1946, and the August, 1946, *AAAS Bulletin*. A special committee has been organized to direct this activity. Special display booths are available without cost and scientists who wish to present the results of their recent research are urged to reguest space application blanks immediately.

For full information about the Exhibition write to

THEODORE J. CHRISTENSEN, *Director*
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THE SCIENTIFIC MONTHLY

SEPTEMBER 1946

THE DETERIORATION OF MATERIEL IN THE TROPICS*

By W. G. HUTCHINSON

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IN SPITE of considerable experience in the use of military equipment in the Philippine Islands and in the Panama Canal Zone the United States approached World War II surprisingly unprepared to carry on any military engagements in the humid tropics. Some of our Allies were equally unprepared in spite of even longer experience in tropical areas. Consequently, enormous quantities of equipment of all kinds which had been produced for use in temperate climates were sent to humid tropical areas with little, if any, thought of its survival under the devastating conditions of high humidity and other factors which make up a tropical environment. As a result, enormous losses were experienced in many different categories of military materials. Textiles and textile products were rapidly weakened and disintegrated by the action of cellulose-destroying fungi and bacteria. In an environment in which the relative humidity might almost continuously be 90 percent or more, such organisms grew in practically unrestricted fashion. In various types of electrical equipment extensive growth of molds was common on hook-up wires and on terminal blocks. Such growth was often accompanied by failure of the instrument. In optical instruments which were satisfactorily sealed for efficient operation in a temperate climate the inner glass surfaces of prisms and lenses became so overgrown with fungi, which brought about an etching of glass, that the instruments required careful overhauling in the field or, in many instances, had to be discarded and replaced by new instruments. Cork gaskets, shock pads, etc., disintegrated relatively quickly under the influence of mold and bacterial growth. Equipment consisting entirely or in part of leather was very heavily overgrown by mold of several types. The stitching in such equipment was often readily destroyed by cellulose-destroying organisms so that the equipment might fail to hold together. Photographic films became badly fungus-

* This paper is based upon studies made at the University of Pennsylvania and in the Panama Canal Zone under Contract OEM-sr-205 with the Office of Scientific Research and Development. At first under the direction of Section 16.1, this Contract was later transferred to the Tropical Deterioration Administrative Committee. Various aspects of the work have been conducted in collaboration with the following subcommittees: Coordination of Test Methods; Optical Instruments; Electrical and Electronic Equipment; Photographic Equipment and Supplies; Synthetic Resins, Plastics and Plasticizers; and Textiles and Cordage. Microfilm copies of the *Official Summary Technical Report* of the over-all activities of the Tropical Deterioration Administrative Committee can be obtained from the Office of the Publications Board, Department of Commerce, Washington 25, D. C.

spotted during storage even though precautions were taken in such storage to prevent high temperatures and excessively high humidities. Wood and wood products, including paper, were also subject to severe attack by microorganisms.

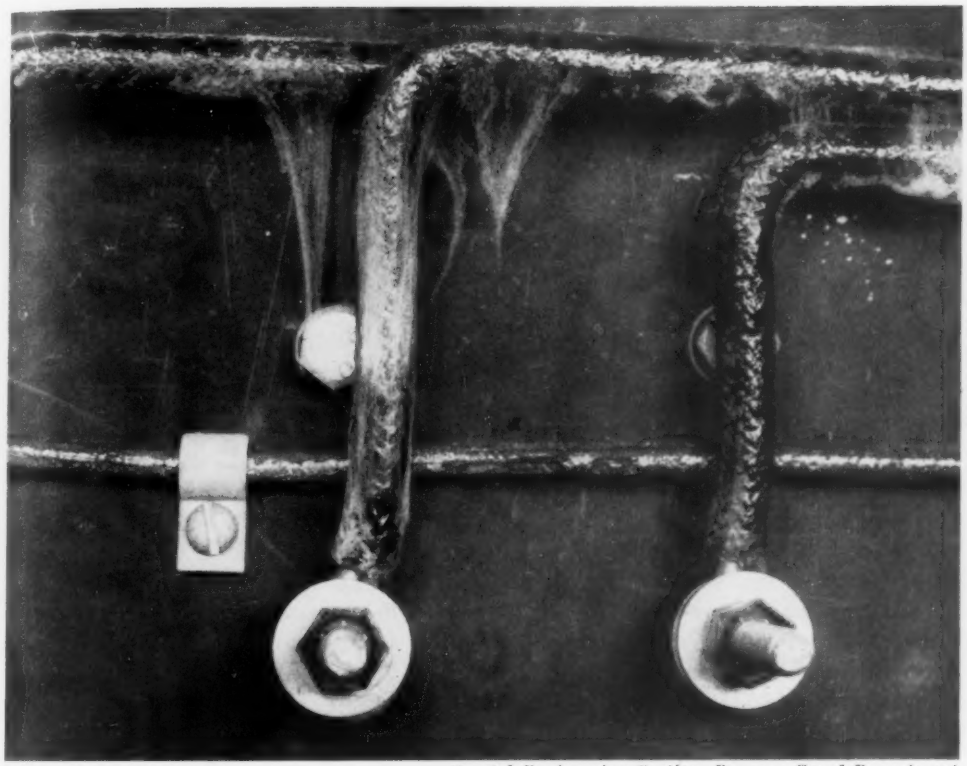
Although this paper is concerned with the activities of fungus or bacterial organisms in inducing deterioration, it should be pointed out that in a tropical environment materials may be subjected to other deleterious effects. Metallic corrosion is an ever-present problem in warm, humid areas. Termites present especially serious problems in connection with wood and wood products. Photochemical disintegration becomes important in textile deterioration. High humidity and accompanying condensation may have serious effects upon the operation of electric and electronic equipment.

It must be borne in mind that such deterioration as cited above is not general in all tropical areas but is confined to the humid tropics. It may be said that the humid tropics are characterized climatically by a consistently high relative humidity, a relatively high temperature, a narrow range of temperature, a relatively high rainfall or a consistent distribution throughout the year of a moderate rainfall, and, finally, lack of excessive drying winds. Such variation in one or more of these climatic factors may occur within relatively small areas that the extent of deterioration may be consequently very variable. For instance, in New Guinea, where great loss of materials by fungus and bacterial deterioration was experienced, there are certain areas which cannot be said to be characteristic of the humid tropics and in which little, if any, deterioration occurred. It is of course unsafe to postulate that an area which receives heavy rainfall must be an area in which deterioration will be experienced. Heavy rainfall may be followed by drying winds to such an extent that the area may be relatively free from difficulty while, on the other hand, an area in which the rainfall is relatively light may have such a distribution of this rainfall throughout the year that the area may be particularly noteworthy as a region of excessive deterioration.

A "dry season," which may occur during some portion of the year in the humid tropics, may be characterized by light rain or almost entire lack of rain, sometimes by drying winds and consequently by a much lowered relative humidity. During this season many of the tropical trees lose their leaves, the soil may become dried and cracked, and much of the vegetation becomes brown and dry. During such periods deterioration is much less rapid or may be entirely absent as equipment may become well dried out. However, in some tropical areas, even during the dry season, relative humidity may remain very high, especially at night, and there may be such heavy condensation in the early morning that equipment will be thoroughly wetted. Optical instruments may show initiation of infection during such dry periods.

The observation has been made repeatedly that certain types of equipment which have dried to the point of cracking or checking during the dry season may become especially susceptible to fungus attack with the onset of the wet season. A climate in which wet and dry seasons alternate may therefore be a more detrimental one for some equipment than a climate in which there is a continuous high humidity. Plywood, for instance, may remain relatively free from fungus damage during months of wet weather. After drying during the dry season, however, it may become badly deteriorated as moisture increases with the advent of the following wet season.

A brief résumé of the problem of deterioration as it affects different classes of materials is presented in the following sections together with some possible measures of control. No attempt is made



Special Engineering Section, Panama Canal Department

FIG. 1. CABLE-LIKE GROWTH OF FUNGI IN A TRANSFORMER

SUCH GROWTH, OCCCURRING ON UNTREATED COTTON-BRAID HOOK-UP WIRES, MAY CAUSE A SHORT CIRCUIT.

here to summarize all control methods; particularly those which have been found effective in the experience of the author are considered.

Electrical Instruments. Much electrical and electronic equipment prepared for use within the territorial United States has proved completely unserviceable after a short period of use or storage in humid tropical areas. Frequently such equipment has shown heavy mold development, especially on hook-up wires and terminal blocks. Although it is possible that functional failure may be primarily associated with moisture rather than directly with the mold, it is certain that a heavy fungus fringe on a hook-up wire will retain moisture which might otherwise evaporate. To the operation man in the field the mere presence of a mass of mold within his instrument is indicative of trouble.

Under certain conditions, fungus development within electrical and electronic instruments may become sufficiently extensive to form cable-like extensions which may bridge from one wire or terminal to another and thus may conceivably be responsible for shorting. Figure 1 represents a situation of this sort in a transformer in the Panama Canal Zone.

Fungi which have most commonly been found associated with hook-up wires in humid tropical areas are species of *Aspergillus*, *Monilia*, *Mucor*, *Penicillium*, *Rhizopus*, and *Trichoderma*.

In an attempt to control the development of fungi within electrical equipment, several remedial measures have been tried. A varnish or lacquer has

been sprayed over hook-up wires and terminal blocks, or over the entire assembled equipment after masking certain critical parts. While probably no varnish or lacquer is completely moisture-proof, the application of such a substance does tend to keep various parts of the equipment relatively dry. However, some of these varnishes and lacquers will, of themselves, support mold growth. For this reason, much work has been done on the incorporation of effective fungicides into lacquers and varnishes. Various branches of the services have been so stringent in their requirements for clean electrical equipment that they have specified that no hook-up wire shall be acceptable if it is able to support any fungus growth. To meet this specification it has been necessary for manufacturers to add some fungicidal material to the lacquer or varnish. Those which have been found most successful for this purpose are salicylanilide and pentachlorophenol. A number of the organic mercury compounds are very effective fungicides, but their use has been discouraged because it is reported that they may produce damage in selenium rectifiers.

A remedial measure that has proved very effective is the substitution of some material which does not support fungus growth for the cotton braid so often used in wrapping hook-up wires. Glass braid, asbestos, cellulose acetate, and various synthetic fibers and plastics have been used for this purpose with considerable success. However, many of these materials have presented production problems which could not well be met during the stress of wartime conditions.

A method of controlling fungus development within electrical equipment which has been found highly effective in the field is the generation of heat within the instrument sufficient to keep the temperature inside the instrument above that of the ambient temperature so that condensation will not occur on hook-up wires and other parts of the equipment. In other cases the equipment has been kept relatively dry by constant forced ventilation.

Optical Instruments. It has been known for many years that the glass surfaces of optical instruments kept in tropical regions are subject to deterioration from the formation of cloudy and splotchy films or granular incrustations, due to leaching or other chemical or physical phenomena, and filamentous tracery, resulting from mold growth on the glass surface. This surface "tarnishing" may appear on new or freshly cleaned optical elements after one to six months in the tropics. While reports of such damage have been common throughout all humid tropical regions, particularly heavy damage had been recorded prior to the recent war from the Canal Zone, Malaya, and the Philippines. Recent reports indicate that there has been severe damage to optical instruments throughout extensive areas of the Pacific war theaters.

Fouled optical glass may interfere with the efficient operation of an instrument in two ways: (1) If the affected area is on some internal part, such as a reticle which is continually in focus, there may be sufficient interference and loss of light to impair greatly the usefulness of the instrument. Such instruments must be sent to a repair shop for cleaning. A fungus spot on the reticle of a director telescope has been seen to block vision so competely that it was impossible to follow the course of an approaching plane. In Figure 2 is shown a spot of tangled fungus growth on a reticle surface which could cause considerable interference with vision. (2) If optical parts are allowed to remain without cleaning, permanent damage may result from the etching of the glass surfaces, which must then either be repolished or the elements replaced. The trouble and expense of the cleaning and

replacing of damaged optical elements together with the fact that essential optical instruments may be out of service from time to time and ultimately show a considerably shortened life have made it an urgent necessity to find methods for eliminating, or at least retarding, this damage.

Sealed optical instruments may become fungus-infested on the internal glass surfaces by direct fungus invasion of the instrument or by introduction of fungus spores there by small animal vectors. Dr. Frank L. Jones,[2] Chairman of the Sub-Committee on Optical Instruments, has pointed out that mites are almost always found within fouled instruments returned from the tropics for cleaning and repair. Figure 3 shows a dead mite on the surface of a binocular reticle with fungus filaments arising from its body. Fungus spores provided with such organic nutrient as a mite body, mite feces, dead fungus filaments or spores, microscopic fragments of cork, wax, or other detritus may germinate in condensed moisture and form a

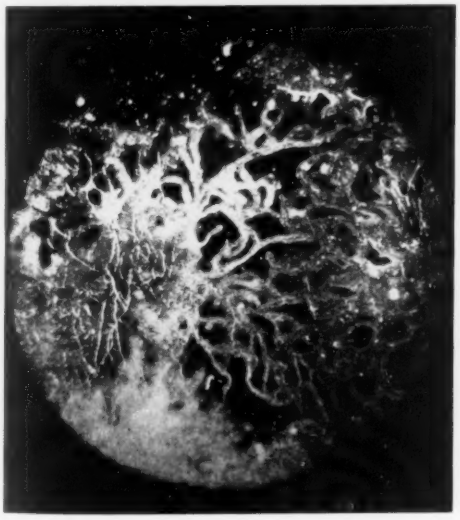


FIG. 2. FUNGUS–FOULED RETICLE
DARK-FIELD PHOTOMICROGRAPH OF FUNGUS GROWTH ON A RETICLE FROM A BINOCULAR IN THE CANAL ZONE. NOTE "FROSTING" OF GLASS WHICH ACCOMPANIES GROWTH OF FUNGUS FILAMENTS. (×50).

FIG. 3. MITE AND FUNGUS
A GROWTH OF FUNGUS FILAMENTS FROM THE DEAD BODY OF A MITE ON THE RETICLE OF A BINOCULAR. SPECIMEN FROM THE PANAMA CANAL ZONE. (×80).

radiating fungus spot upon the glass. There is no evidence that the fungus obtains any mineral nutrients from the glass itself. That fungus-fouling is not necessarily dependent upon mite infestation is shown by Figure 4. Chemically clean glass was inoculated with masses of fungus spores. The spots shown here developed from the growth of certain spores which apparently secured their nutrient from masses of ungerminated, partially lysed spores.

A filamentous tracery of relatively deep etching may develop upon glass surfaces which have long been overgrown with fungus mycelium. Although no precise data are available on the mechanism of such etching, it is probable that the water film surrounding each fungus filament promotes leaching of some of the glass constituents. That some of the excreted fungus metabolites may hasten such leaching may only be surmised until evidence is obtained.

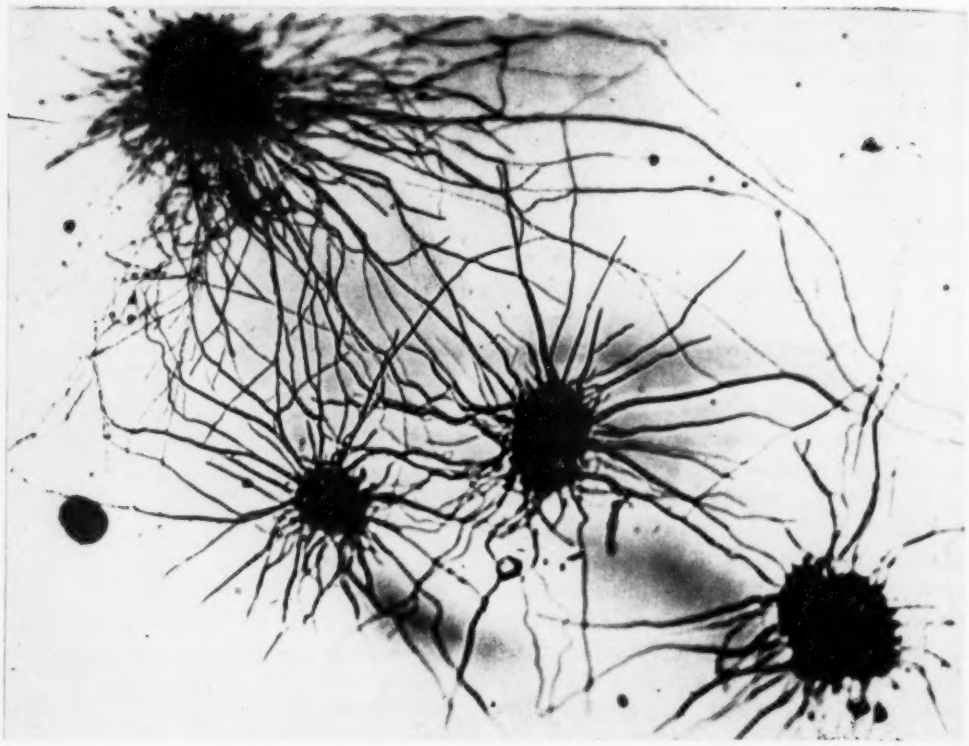


FIG. 4. FILAMENTS RADIATING FROM SPORE MASSES ON GLASS
PRODUCED BY SPRINKLING SPORES ON CLEAN GLASS AND INCUBATING AT A HIGH HUMIDITY. (×50).

The fungi associated with this fouling of optical surfaces are not of any unusual sort but are common, widely distributed molds. *Monilia crassa* and several species of *Aspergillus* and *Penicillium* have most commonly been isolated from glass in the Panama Canal Zone. All of these may be seen sporulating on the optical surfaces.

Binoculars and other optical equipment of recent design may be so well sealed that the penetration of fungi or their vectors may be impossible. However, many thousands of optical instruments used in tropical regions during the war were not so sealed. It has been found possible to prevent the development of fungi within such instruments by the use of a volatile fungicide. Metacresyl acetate, known commercially as cresatin, incorporated into an ethyl cellulose base, may be placed into small metal capsules from which it will evaporate very slowly. These may be fastened to the inner surfaces of optical equipment, safely out of the path of light. One such capsule per chamber has kept binoculars free from mold growth for as long as two years. Sodium ethyl mercury thiosalicylate, or merthiolate, has been used on aerial cameras with success by the Australians in preventing fungus encroachment upon the lenses.

Proper storage of cameras, microscopes, and other optical equipment will effectively prevent fungus fouling.

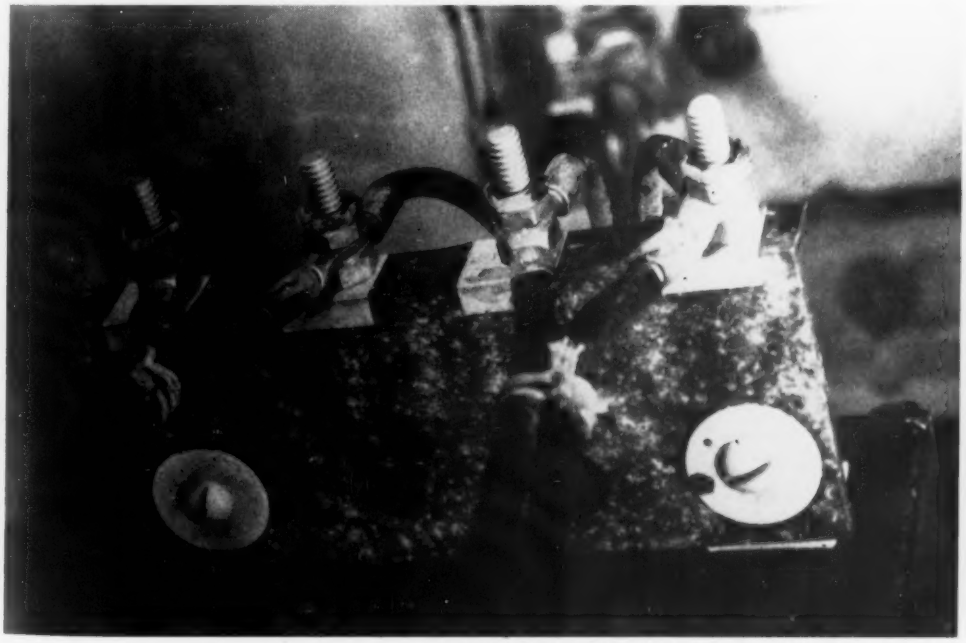
Cork. Various materials composed of cork may be seriously damaged by the action of microorganisms. The cork pads so often used in optical equipment serve as a source of nutrient for fungi, which may spread extensively over glass surfaces from the infected cork. The cork

lining of aerial camera cones has supported such luxuriant fungus growth that much of the instrument might be overgrown with mold or showered with mold spores.

The impregnation of cork with 2 percent paranitrophenol dissolved in amyl acetate has kept cork free from attack by molds for an exposure period of six months in the Canal Zone, whereas untreated samples became heavily overgrown in three to five days. Similarly treated samples have remained clean in the tropical house at the University of Pennsylvania for fifteen months.

Plastics. Modern plastics have found important uses in many types of military equipment. As vital parts of electrical or optical equipment and as substitutes for leather, cork, wood, and metal in many service materials, plastics have been subjected to the deleterious effects of the humid tropics. Under the influence of moisture and microbiological activity these plastics have suffered various damage. Some of the laminated plastics have developed checking and separation of components. Plastic surfaces have become crazed, blistered, or whitened. Certain types of plastics have developed extensive molding. Figure 5 illustrates a plastic terminal block from a transformer in the Panama Canal Zone with mold growth over much of its surface. Such mold growth may result in the etching of the plastic surface, may have some effect upon the electrical resistance of constituents of electrical and electronic equipment, or may cause severe reduction in light transmission when a sheet plastic is used as an instrument window.

A variety of fungi are encountered in association with plastics. Laminated plastics may be attacked by such cellulose-decomposing organisms as *Chaetomium*, *Curvularia*, *Memnoniella*, or *Metarrhizium*. Several species of *Aspergillus* and *Penicillium*, especially *A. chevalieri* and *P. luteum*, have been isolated from infected plastics in the tropics.



Special Engineering Section, Panama Canal Department

FIG. 5. FUNGUS GROWTH ON A PLASTIC TERMINAL BLOCK

Plastics that have been shown to be resistant to fungus growth should be chosen for tropical use. Little has as yet been done to develop fungicidal or fungistatic plastic surfaces by the incorporation of fungus poisons into plastics.

Photographic Film. The deterioration of photographic film in the humid tropics, resulting from fungus attack and moisture, is a problem which has been recognized wherever photographic work has been done under tropical conditions. The recent war has high-lighted this problem because of the great loss that has been experienced not only in unexposed film in rolls, packs, and packages but also in the exposed and developed film negatives which have been filed and stored for reference. A tropical packaging of films was developed which has been very effective in preventing loss of unprocessed film. Stored processed film, however, has presented a difficult problem. These stored negatives often became spotted with numerous deep blue patches which have the general outline of fungus colonies. Figure 6 shows a photograph of such a spotted negative. Printing by projection from negatives spotted in this manner results in white or light-colored areas on the print in regions where the blue spotting appeared on the negative. This particular condition has been noted only on the backing of those film materials which have a blue dye incorporated in the antihalation coating. The mycelia growing on the emulsion surface of such film are not associated with any color change. A less striking but even more serious phase of microbiological deterioration is the etching of the surfaces of the negative by microorganisms.

FIG. 6. FUNGUS SPOTTING ON A NEGATIVE

STORED FOR SEVERAL MONTHS IN THE CANAL ZONE, THE ANTIHALATION BACKING OF FILM WAS ATTACKED.

FIG. 7. PORTION OF LAPEL OF COTTON FIELD JACKET

DOTTED WITH FRUITING STRUCTURES OF *Chaetomium globosum*, SEVERAL SUCH JACKETS, THOUGH NEVER ISSUED, HAD DETERIORATED DURING STORAGE IN A WAREHOUSE ON BIAK ISLAND. PHOTO (×2) BY COURTESY DR. W. L. WHITE AND PHOTOGRAPHIC DEPARTMENT, PHILADELPHIA QUARTERMASTER DEPOT.

It has been found possible to prevent fungus deterioration of processed photographic negatives by use of one of the commercial quaternary ammonium compounds. Roccal (high molecular alkyl-dimethyl-benzyl-ammonium chlorides) in a dilution of 1 part of the commercial solution in 10 parts of water makes a fungicidal bath into which films may be momentarily dipped. Such treated films have remained free of fungus attack under simulated tropical exposure in the Tropical House at the University of Pennsylvania for more than 5 months. Untreated film has developed fungus spotting within two weeks. Tests performed by one of the well-known manufacturers of films have shown that no detrimental effects to the film occur with a Roccal dilution of 1 part in 10 parts of water.

Textiles. Various types of textile products may be degraded by microorganisms. Fungi may live on the surface of the textile, gaining nutrition primarily from the sizing of the cloth and other fortuitous nutrients and present a superficial "mildewed" appearance. Molds of this sort may not cause any important disintegration of the fibers but are undesirable because of spotting and odors which they produce. The Australians have reported that some of the superficial molds may attack the water-repellent finish of the cloth so that the fabric becomes available for attack by the cellulose-destroying organisms. A number of fungi and bacteria may derive their nutrition directly from the cellulose or other basic constituent of the textile fiber and in this way bring about a fundamental breakdown of the fibers themselves with consequent disintegration of the cloth or other product (Fig. 7).

One is sometimes reminded that if equipment is kept dry in the tropics there will be no problem of deterioration

due to fungi and bacteria. In the case of textiles, as perhaps in no other type of equipment, it becomes completely impossible to maintain dryness, for many textile products are used primarily to keep other materials dry. Canvas tents, tarpaulins, canvas covers for fire control equipment, etc., must be exposed directly to the elements to fulfill their intended purpose. Such materials are thus subjected to deterioration not only as a result of attack by microorganisms but also that brought about by exposure to sunlight and alternate wetting and drying.

The problem of treating textiles becomes a complex one indeed when one realizes that in addition to the necessity of impregnating the material with some fungus inhibitor it is essential also to make the cloth water-repellent and oftentimes fireproof as well.

The Quartermaster program of research on textile deterioration with its emphasis on investigation in tropical areas is a commendable one.

Tropical Storage. Military warehouses in permanent tropical installations are commonly equipped with air conditioning. In some instances, however, air conditioning has been assumed to mean raising the temperature above that of the ambient with no accompanying ventilation. This has resulted in an atmosphere high in moisture content and well adapted to fungus development. Where air conditioning has resulted in dehumidification of air, storage has proved highly successful.

Heated closets or chests, often referred to as "dry closets" or "dry chests," have proved highly effective in the humid tropics for the storage of various equipment. In fact, in many tropical areas no home is without its "dry closet" for storing clothing, linens, cameras, and other materials which might "mildew" or become damaged by moisture. When properly constructed and ventilated, these heated closets are effective drying units. However, they are usually built with little thought of the principle involved in their proper function. Commonly, every effort is made to make the construction as airtight as possible. As a matter of fact, the unit can function in drying only when there is provision for proper ventilation. The principle involved in ventilation is as follows: Moisture-laden air enters at the temperature prevailing outside the chamber. When it is heated, it must take on additional moisture which it secures from the materials within the chamber. This heated air, laden with additional moisture, then rises to the top and passes out the vent. If no ventilation is provided, both temperature and humidity remain high, and no value is secured by this type of storage. If too much ventilation is provided, the air is not properly heated and there may be little, if any, drying effect upon the contents of the closet. In Figure 8 a storage closet is pictured showing heaters and type of ventilation found satisfactory.

Heating is usually accomplished by a series of electric bulbs or by small strip heaters such as are sometimes used to prevent rusting and mildewing in pianos during humid weather. The amount of heat to be supplied must be determined by trial. A temperature differential between the inside of the closet and the outside of 10° to 15° F. will usually keep the relative humidity at a point where storage is safe. It is important to check the temperature frequently, especially during the first days of use. Temperatures over 120° F. should be avoided. Portable chests of this sort have been used with excellent results in the Pacific war theaters for storing aerial cameras and other optical equipment.

When it is necessary to store equipment in an area where electric current is not available, a similar dry locker or chest may be used in which the drying is accomplished by a chemical desiccant

FIG. 8. TWO PHOTOGRAPHS OF A "DRY CLOSET"
Left: CLOSED DOOR WITH VENTILATION HOLES. *Right:* HEATING UNIT AND STORAGE FACILITIES INSIDE.

rather than by heat. Silica gel, freshly baked for two hours at 250° F., should be placed in a chest constructed with special care to make it airtight and in which no ventilation is provided. One pound of such silica gel for each two cubic feet of content may keep the humidity in such a chest within a safe range for a month, provided the chest is opened infrequently. Silica gel containing cobalt chloride indicator should be used. As soon as it has turned from blue to pink it should be rebaked at once.

Acceptance Testing of Materials. If materials susceptible to fungus attack in the tropics are to be replaced by those naturally resistant to fungi or made resistant by the incorporation of fungicides, it becomes essential to evaluate many classes of materials with respect to fungus resistance. Such acceptance testing has been practiced in industrial and service laboratories since its need became evident. However, the methods used in the tests have differed so markedly that results have been much at variance between different laboratories. The need for coordination and standardization of these methods became evident.

Evaluation of such materials as hookup wires, plastics, coating materials, treated cork and leather, photographic films, and many other constituents of elaborate equipment may be made by three possible test procedures: laboratory

FIG. 9. APPROACH TO BARRO COLORADO ISLAND FROM GATUN LAKE
THE BUILDINGS AT THE TOP OF THE HILL HAVE BEEN USED AS A TEMPORARY TROPICAL STATION FOR THE STUDY OF DETERIORATION. OPEN EXPOSURE AREAS AND PROTECTED CHAMBERS WERE USED IN JUNGLE.

testing by accelerated methods, testing in tropical rooms under simulated tropical conditions, and testing in the tropics.

While ultimate decision with respect to the usefulness of a material must be based upon its behavior in the tropics, it is impossible to await results of relatively long tropical exposure for all classes of materials. It is essential that a certain amount of laboratory testing be done to provide tentative answers with as little delay as possible. It then follows that the methods of testing must simulate tropical conditions and introduce no factors other than those encountered in a tropical environment.

An extensively used acceptance test for hook-up wires and coating materials evaluates the samples on a nutrient medium inoculated with fungus spores. The molds make a vigorous growth on the medium but do not grow into a specified "zone of inhibition" if the material is to receive a favorable rating. This zone does not measure the ability of the test specimen to support growth but the diffusability of some water-miscible fungus inhibitor contained in the specimen. A method devised for the Sub-Committee on Coordination of Test Methods substitutes a mineral salts culture medium containing no organic nutrient. The test specimen itself must therefore contribute the organic nutrient to support fungus growth. Hence a favorable rating is received only if the fungus inoculum is unable to make any marked development on the sample.

Any testing performed *in vitro* must be considered as a screening test and must be regarded as reliable only to the extent that its results can be shown to correspond with those of tropical exposure.

Testing of materials in so-called "tropical rooms" has received much attention during the war. At the University of Pennsylvania such a testing room has been in operation for over two years. By automatic cycling the average diurnal temperature and relative humidity range of the humid tropics may be duplicated. A quantity of leaf litter from tropical plants is kept inoculated with several tropical strains of molds and with mites and several small insect vectors of molds. It is believed that such a unit or the larger one recently described by Cooke and Vicklund[1] represents as faithful a simulation of a tropical environment as may be secured in the Temperate Zone. It should be pointed out, however, that a complete tropical environment may be impossible to duplicate in all its climatic, biological, and physical details.

For the University of Pennsylvania tropical room it has been shown that the deterioration of optical instruments, cork, packaged rations, leather, and plastics proceeds at about the same rate as occurs in the Panama Canal Zone during the rainy season.

With the realization that evaluation of materials by testing *in vitro* or in tropical chambers can be meaningful only in the light of correlation with actual tropical exposure, a laboratory for testing and research was established in the Panama Canal Zone early in 1944. Through the courtesy of the Board of Directors of the Canal Zone Biological Area this laboratory was established at Barro Colorado Island in Gatun Lake. In Figure 8 is shown the approach to the island with the laboratories and living quarters made available for the men working on tropical deterioration. Because of the character of vegetation of the surrounding jungle and climatic factors this region has been described[3] as similar to a monsoon forest area. During eight months conditions for testing equipment under humid jungle conditions are ideal. A dry season of about four months results in drying out of materials exposed out-of-doors. However, in closed exposure chambers the relative humidity has remained sufficiently high throughout the dry season to induce molding of leather, cork, plastics, hook-up wires, and optical instruments. Over fourteen thousand items of service materials have been tested at Barro Colorado Island for resistance to fungus attack. A collection of microorganisms associated with deteriorated samples has been made and sent to the tropical fungus collection maintained at Harvard University. In the case of several test materials, replicates have been tested by *in vitro* methods, by tropical room exposure, and by exposure at Barro Colorado Island. It has thus been possible to correlate to some extent these laboratory methods with actual tropical exposure.

To a microbiologist humid tropical areas represent regions replete with possibilities for investigation. Problems of deterioration can be studied far more effectively in the areas where they occur than in far distant laboratories. Military experience in the humid tropics has brought to light many problems other than those of deterioration that require investigation. Problems in medicine, public health, engineering, chemistry, geology, and all branches of biology are familiar to scientists acquainted with these areas. Thought should be given to the establishment of some scientific center in the humid tropics for the study of problems peculiar to those regions.

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WHAT SOUND HATH WROUGHT—II*

By NATHAN LEVINSON

WARNER BROS. PICTURES

WITH the introduction of the sound picture came the creation of the studio Sound Department. The personnel of this department is headed by the Director of Sound Recording, whose position is both administrative and technical in character. He has complete authority with respect to the operations of his department, and it is his responsibility to secure the best recording possible at a reasonable cost of operation and under a wide variety of recording conditions. Although engaged in work highly technical in character, the Sound Director must be appreciative of the fact that he is surrounded by people in many branches of the creative arts, and his success is largely determined by his ability to coordinate the technical efforts of his department with the functions of other studio groups. In many instances the Sound Director exercises some control over the processing of photographic sound records by the film laboratory, and he is vitally concerned with the quality of sound reproduction of his product in the theater.

The varied nature of the problems confronting the Sound Director requires that he have a number of capable assistants to handle the many operations with which his department is concerned. The Chief Engineer is responsible for all the purely technical phases of sound department operation, including the installation, operation, and maintenance of studio recording and reproducing equipment and the development of improvements in technical facilities. The Chief Mixer provides the working contact between the Sound Director and the various staff units working on each picture. He checks the daily product of the Sound Department and assumes responsibility for the techniques and practices of the sound crews assigned to production units. Supervision over those men who actually operate the recording machines is frequently delegated to a Chief Recorder. The operation and maintenance of recording circuits and associated equipment are supervised by one or more Transmission Engineers, who are responsible to the Chief Engineer.

Since the introduction of film recording, the sound crew assigned to a production unit normally consists of four men. This group is headed by the Mixer, who is directly responsible for proper positioning of the microphones on the set, control of the sound volume recorded, and for the acceptance or rejection of each recording made on the basis of the quality and perspective of the sound as judged through his monitoring system. The Mixer often has a technical background, although this is not a specific requirement for his work. He should be capable of critical appreciation of the quality and general character of the sound required to match the action on the motion-picture set.

The Mixer generally has two assistants known as Stage Helpers, whose duties consist of providing proper suspension for the microphones, connection of the various microphones to their associated amplifiers and to the mixing equipment, and the general execution of the Mixer's instructions as to the handling of the microphones during recording.

The remaining member of the sound crew is the Recorder, who is responsible for the operation of the recording ma-

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THE SOUND MIXER

IN THE MONITOR ROOM THE MUSICAL DIRECTOR LISTENS INTENTLY AS THE SOUND MIXER SWELLS AND MODULATES THE MUSIC OF A SYMPHONY ORCHESTRA BELOW, WHICH IS RECORDING THE SCORE FOR *Juarez*.

chine and its auxiliary equipment, and in some cases for the operation and maintenance of all the recording channel equipment. This man is usually a highly trained technician who possesses at least a working knowledge of the fundamental principles of amplifier operation and testing, optical system adjustments, and film recording and processing techinques.

The daily product of Sound Department operations appears in the form of a number of film sound takes, each of which is matched by a corresponding picture scene, or take. After both picture and sound have been checked and approved by the producer of the picture, the director, and the Sound Department, they are delivered to the studio Editing Department. Here the picture editor proceeds with the assembly of the various scenes in a sequence which is believed most suitable for the presentation of the story involved in the picture. The assembled lengths of picture and sound track prints are accurately synchronized with the aid of synchronizing marks photographed on both the picture and sound film.

Within a period of one to three weeks after the last scenes of a picture have been photographed, the Editing Department will have produced a so-called rough cut print of the picture. The length of the picture at this stage may be 3,000 or 4,000 feet greater than that of the picture in its final form. The producer of the picture, the director, the head of the Editing Department, and the picture editor then project the picture a number of times to determine whether the sequence in which the scenes

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have been assembled is the most advantageous that can be devised, whether certain scenes should be deleted from the picture to secure improved tempo, and whether any retakes are necessary to provide a smoothly moving narrative. The picture is then re-edited and is again reviewed to determine what further improvements can be made by shortening or deleting scenes or by rearrangement of their sequence. This process is repeated as often as is deemed necessary to secure the maximum dramatic value from the story. The length of the average fully edited feature picture is of the order of 9,000 feet.

Sometime prior to completion of the editing process, the Editing Department will order the production of the necessary lap dissolves, wipes, fades, montages, and other special photographic effects required for a smooth and effective presentation of the screen story. After these elements have been introduced into their proper places in the pictures, the edited picture print or a copy thereof is turned over to the Music Department for preparation of the musical score.

One of the most important adjuncts of the sound motion picture is its accompanying synchronized musical score. Under present production techniques the musical score for a picture is prepared after editing of the picture has been completed.

This technique could not, unfortunately, be employed prior to the development of methods of re-recording sections of original sound records to a final release record. During the production of early sound pictures, when all sound records took the form of disc recordings, such music as was required for a picture had to be produced on the sets employed for the picture. Keeping in mind the fact that it was necessary to record and photograph all sound and action required for a single reel of film in one continuous operation, one can well imagine the difficulties of securing a perfect continuous performance by actors and actresses as well as the recording orchestra over the period of eight to eleven minutes required for the production of a single record. Special music had to be written for each reel of film, and a great many rehearsals were required before both players and orchestra had sufficiently familiarized themselves with their parts to permit an attempt at recording and photographing the scenes comprising a reel of film entertainment.

The need for the preparation of special music for every picture led to the organization of a Music Department in each of the studios. Some of the country's finest composers, arrangers, and conductors rapidly acquired the technique of adapting existing musical scores or preparing original scores for the rapidly growing sound-picture industry, and from their efforts have come the endless succession of hits in the field of popular music.

The scoring of sound pictures was greatly simplified when disc recording gave way to the photographic process. Since a film record could be quickly and conveniently edited in the same manner as picture film, the need for scoring complete reels of picture in one operation no longer existed, and modern scoring techniques came into being. The typical feature picture is scored by a studio orchestra maintained for this purpose, although occasionally the more pretentious pictures employ the services of various nationally and internationally known musical groups. The score for every picture is written to suit the moods and tempo of the various scenes, and the music prepared for one picture is seldom, if ever, later employed in another.

As soon as the scenes of a picture have been assembled in the sequence believed most desirable, the Director of the Music Department assigns a composer and an

RECORDING SOUND

SOUND FROM THE MIXER IS RECORDED BY THE LATEST TYPE OF RECORDING APPARATUS.

orchestrater to the preparation of a musical score particularly suited to that picture. The picture is projected several times to enable the composer and orchestrater to familiarize themselves with the situations, moods, and tempo of the picture subject matter. The producer of the picture, the musical director, the composer, and the orchestrater then discuss and decide which of the picture sequences should be provided with a musical score. The nature of the underlying musical theme may also be discussed at this time.

Each sequence of the picture is then carefully timed on moviola equipment, and detailed cue sheets containing information with respect to all the important action and dialogue of the picture are prepared to aid the composer in most effectively fitting each musical sequence to the corresponding picture.

The composer's task is essentially one of creation, the effectiveness of his work being measured by the degree to which the musical score enhances the dramatic effect of the picture. An effective musical score may be brilliant, dynamic, or subdued, but it must never attract attention at the expense of the picture.

The composer prepares his material in the form of a piano sketch and generally indicates which sections of the orchestra are to be employed for the various musical sequences. The orchestrater, or arranger, employing the composer's sketch as a guide, assigns a voice to each individual instrument so as to obtain proper tonal balance in the final orchestration. When the nature of the picture so demands, the arranger may completely alter the tempo and character of a section of the theme to dramatically emphasize certain picture sequences.

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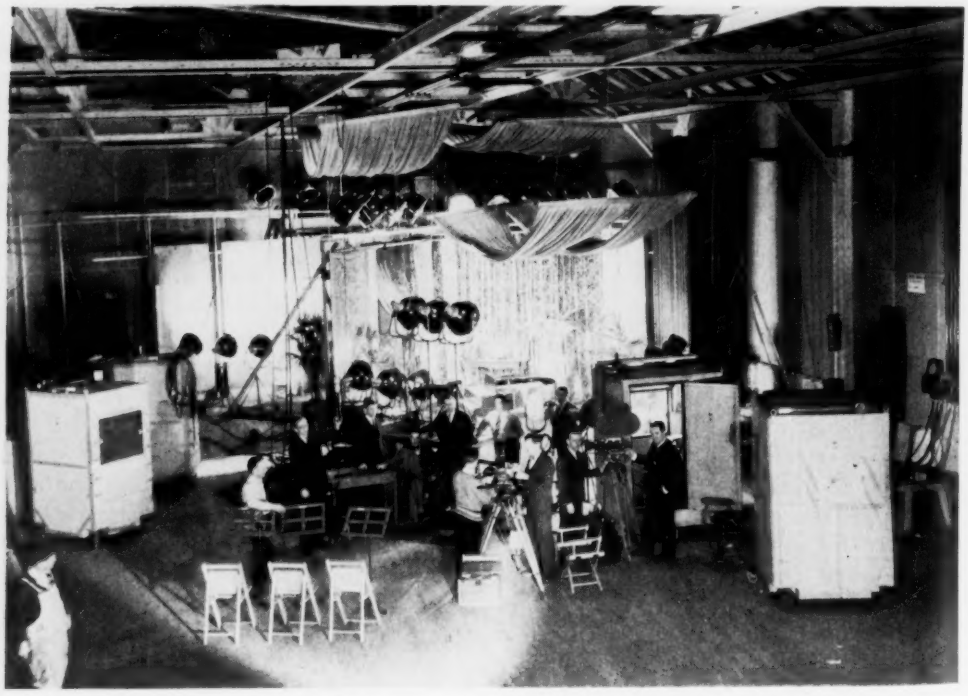
With the completion of the orchestration, the arranger's material is turned over to a staff of copyists, who extract the individual instrumental scores from the orchestration. A music proofreader, who is usually a capable composer, checks the final score for errors, after which the music is printed in suitable form for the orchestra.

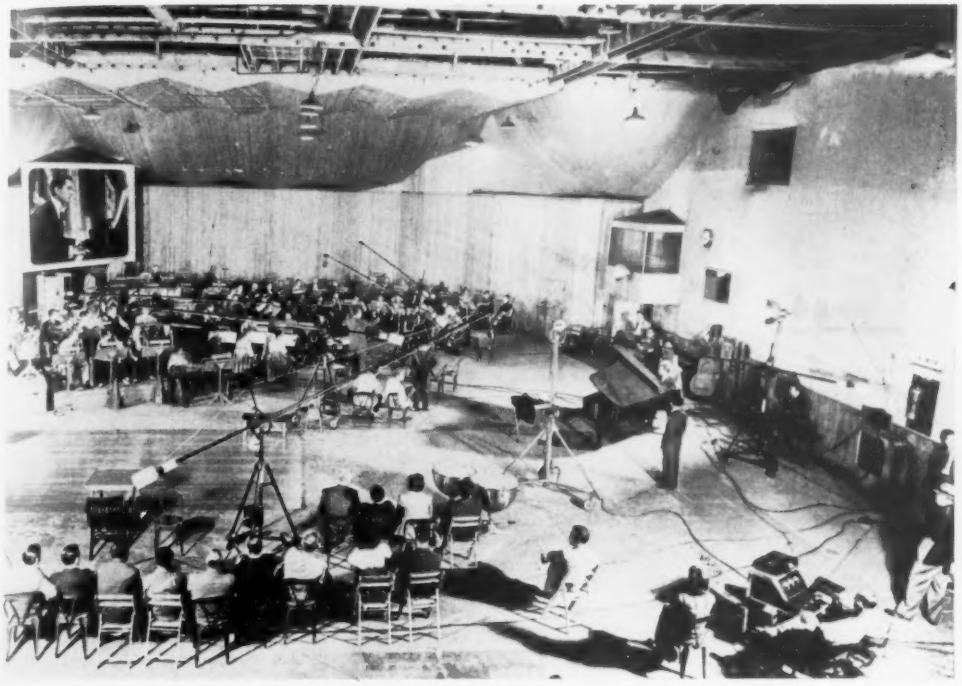
The procedure outlined above is generally followed in the production of all pictures except those which feature musical numbers or elaborate dance sequences. In the case of such pictures, a composer is assigned to the preparation of the musical score as soon as the picture script has been completed, in order that the score required for the special sequences may be available before the corresponding scenes are photographed. A recording of the music for these sequences is then made in the normal manner on both film and disc records. The disc records are reproduced on the stage at the time that these sequences are photographed, so that the action may be perfectly synchronized with the musical score. No sound is recorded while the scene is photographed, since the original film record of the musical score will be in exact synchronism with the action and may be employed in the final re-recording process.

Most picture scoring is carried out on stages which have been specifically designed for this purpose. The general stage construction is similar to that of other sound stages, differing principally in that the acoustic treatment of walls, floor, and ceiling is given greater consideration. A motion-picture screen fitted to the stage wall in such a position as to be clearly visible to the orchestra conductor and the sound mixer, together with appropriate motion-picture projection equipment, enables those immediately concerned to accurately fit the tempo and length of each musical se-



EARLY MUSICAL RECORDING

PREPARATION IS MADE TO SHOOT THE MUSICAL SCENE. NOTE THE SOUNDPROOF BOOTHS ON THE STAGE.



RECORDING MUSIC

THE MUSIC IS PLAYED TO MATCH THE FILM WHICH IS PROJECTED ON A SMALL SCREEN IN THE CORNER.

quence to the corresponding picture action. The sound-recording equipment employed for scoring is usually identical with that used for production recordings, with the possible exception of more elaborate channel supervisory and intercommunication equipment. Permanent monitoring facilities for the recording channel are set up in monitoring rooms which form a part of the scoring stage, and double plate glass windows afford the sound mixer a view of the musicians, the conductor, and the screen, at the same time providing sufficient sound insulation between the stage and the monitoring room so that the mixer is not confused by sounds from the stage combining with those from his monitor speaker system.

Each reel of the picture is scored in sections, the numerous takes being later spliced to form a continuous sound track. One advantage of this mode of operation lies in the fact that the musicians are able to give a practically flawless performance after a number of brief rehearsals, whereas if an entire reel were scored during a single take the physical and mental strain would be far greater on all concerned. Music scoring as generally practiced is termed a postrecording process, since it is not begun until photography and editing of the picture are completed.

When scoring is completed, the various film records corresponding to the musical sequences for the picture are assembled in precise synchronism with the edited picture print prepared by the studio Editing Department. This operation is conducted under the supervision of a qualified member of the Music Department. During this period the numerous separate film records of necessary sound effects are also synchronized with the action of the picture. The final sound record is secured by re-recording simultaneously the dialogue sound track,

the music sound track, and the sound effects tracks to a release sound negative. Final release prints for the theater are obtained by printing each reel of the edited picture negative and the corresponding re-recorded sound negative on a single length of film. In this manner exact synchronism between picture and sound is assured in the theater.

The process of preparing the final sound record to accompany the picture in the theater is a highly specialized one and is generally conducted by a separate division of the Sound Department. The equipment required for this process is basically similar to that employed for stage recording, with the exception that the microphones are replaced by high-quality film reproducing machines in which the various photographic sound records to be combined in the final release record are reproduced as electrical signals. These signals are combined in proper proportion through suitable control circuits, and the resultant signal is again recorded on film.

The re-recording control console is generally located in a re-recording room designed to simulate, in proportions and acoustic characteristics, a small theater. Motion picture projectors located in a booth adjacent to the re-recording room provide a picture image of theater size on a screen located an appropriate distance in front of the re-recording control console, thus enabling the sound mixer to judge the quality and proper combination of the several sound records being re-recorded for the final sound track in terms of the pictorial effect with which that track is associated.

During the final process of re-recording, the music director, the composer, and the arranger have an opportunity to determine how satisfactorily the musical score matches the moods and tempo of the picture. On many occasions it is found desirable to delete or to lengthen certain musical sequences, and these operations are again conducted under the general supervision of a representative of the Music Department.

All feature pictures are previewed to secure public reaction before the picture is considered completed. Following the preview, and depending largely upon the nature of the preview audience reaction, the picture may be re-edited to strengthen certain sequences or to improve tempo or continuity. In such cases corresponding re-editing of the dialogue, music, and sound effects records is necessary, and a second re-recording operation is required to secure a release sound track which matches the re-edited picture.

THE tangible result of Hollywood's annual production activities takes the form of hundreds of millions of feet of processed motion picture film. Elaborate facilities are provided for developing, fixing, washing, drying, cleaning, waxing, identifying, handling, storing, and shipping this film. All film development is carried out with the aid of continuous processing machines, the solutions employed being continuously filtered and automatically maintained at the optimum temperatures. The finest air conditioning equipment is employed to insure an adequate supply of clean air, of proper temperature and humidity, to all sections of the laboratory buildings.

Much of the present film laboratory equipment and several of the most important film processing techniques have been developed to permit proper processing of photographic sound records.

During the early days of the silent motion picture, film development was accomplished by winding the exposed film on suitable racks and manually submerging rack and film in tanks of developer solution. Fixing and washing of the film was carried out in a similar manner. The quality of development was determined entirely by visual inspection, and varied from hour to hour

THE LATEST TYPE OF EQUIPMENT

A SCENE FROM *Night and Day* ILLUSTRATES A NEW ROVING MICROPHONE AND TECHNICOLOR CAMERA.

and day to day. Nonuniformity in the development of adjacent lengths of film was practically unavoidable and gave rise to so-called "rack flashes," which were manifested by periodic variations in brightness of the picture on the theater screen.

The introduction of machine developing methods did much to overcome the nonuniformity of manual development, but control of the developing process was still based principally upon visual inspection of the final product. Machine processing of release prints preceded that of negative materials by a number of years, a situation that was brought about partly through fear of loss or damage to the more valuable negative film, and partly because the smaller total footage of negative stock involved did not actually necessitate the use of the more rapid processing which machine development provided. Fortunately, continued improvements in the design of processing machines removed all objections to their use for the development of both negative and positive materials, and the advantages provided by machine methods were so attractive that all film was being processed in this manner sometime prior to the introduction of the sound picture.

The first large-scale commercially employed photographic sound records were of the variable density type and required extremely uniform and accurately controlled development to prescribed negative and print gammas to insure satisfactory quality. Such processing could only be secured with the aid of sensitometric control of the degree of film development. Unfortunately, the merits of sensitometry were not widely recognized in the Hollywood laboratories when sound engineers first became concerned with the processing of film records, and

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considerable difficulty was experienced for a time in securing the control of development necessary to insure the production of high quality sound records. The initial ventures of the technically-minded sound engineers into the sacred precincts of the film laboratory were generally regarded with more than a slight shadow of suspicion, and few of the laboratory personnel were interested in learning the finer points in the art of film processing from engineers whose principal acquaintance with the subject had been derived from textbooks. Nevertheless, the virtues of sensitometric control were gradually recognized, and within the space of a few years all motion-picture film processing was based upon the application of fundamentally sound technical procedures.

A number of relatively recent refinements in film laboratory equipment have grown out of studies directed toward the production of sound records of improved quality. For example, a certain amount of high-frequency distortion in the sound record was traced to directional effects in the film processing machines. Modification of the machines to provide adequate turbulation of the developer solutions in contact with the film surface have resulted in pronounced improvement in the quality of both the sound record and the picture image. Another source of high-frequency distortion in sound records was traced to minute slippage between negative and print stocks during the printing operation. Radical modifications in the design of continuous printers led to the manufacture of so-called non-slip printers, which are capable of successfully printing the finest detail that exists on either the picture or sound track negative film. A noticeable improvement in quality of both picture and sound projection in the theater has been evident since these printers were first introduced.

THE rate at which the various activities essential to the production of a sound motion picture are carried out is almost uniformly accelerated from the date of selection of the story material to completion of the picture. The preparation of a production script may occupy a period varying between two months and a year or more. Actual photography of a feature picture normally requires from four to sixteen weeks. Within one to three weeks after photography of the picture is completed, the Editing Department will have provided the Music Department with a complete print of the picture in the form that will be shown at the first preview. From this time until completion of the picture, a large number of highly technical operations must be carried out before the arrival of deadlines for release printing, which may have been set long before photography of the picture was completed.

Not all the changes wrought by the introduction of sound have been confined to the motion picture studio, for the theater has also been affected in several important respects. The requirements of intelligibility of sound in the theater have necessitated considerable attention to the acoustic characteristics of theater auditoriums. In a few cases major structural alterations have been required. In others, such deficiencies as existed have been susceptible to correction through the installation of acoustic treatment in the auditorium and behind the theater screen.

Since the speed of projection of silent films was limited more by the sense of propriety of the theater manager than by technical considerations, it was not unusual for a manager to urge the projectionist to speed up the screening of the better pictures in order that a greater number of showings per day, and therefore a greater audience turnover, might be secured. This procedure frequently detracted very materially from the entertainment value of a pic-

A MODERN TECHNICOLOR CAMERA AND SOUND CRANE

ture. With the introduction of sound pictures the speed of projection of the film had to be equal to that employed during the recording operation in order to avoid distortion of pitch, and a standard projection speed was adopted by the entire industry. This step has resulted in complete uniformity of projection practices in all motion-picture theaters, to the consequent betterment of the entertainment value of all pictures.

The comparatively great variations which originally existed in the quality of sound reproduction in various theaters throughout the country soon led to a program of standardization of frequency-response characteristics of theater sound equipment. This program has been conducted under the auspices of the Research Council of the Academy of Motion Picture Arts and Sciences and has resulted in continually improved theater sound quality. A program leading toward the standardization of theater screen illumination levels has also been under way for some time and has done much to improve the average quality of the theater screen image.

Even a brief survey of the changes wrought by the development of the sound motion picture would be incomplete without some consideration of the cost at which the transformation of the industry was secured. The investment required for the physical recording plant itself may be taken as roughly equal to $100,000 per studio recording or re-recording channel installed. A similar sum would cover the cost of a mobile recording channel. The central recording building and each of the sound stages represented an average investment of the order of $40,000 to $75,000, while the cost of the wiring installed between the recording building and the stages might be presumed to average approximately $7,500 per stage. The

equipment required for each of the studio theaters or review rooms represented an additional outlay of approximately $10,000. Thus, the new plant investment for a studio converting from silent to sound production and requiring six sound stages, four recording channels, two mobile recording channels, and two review rooms would average somewhat more than $1,000,000. Approximately double this amount of equipment was installed by each of the major studios within a few years after full-scale production of sound pictures got under way.

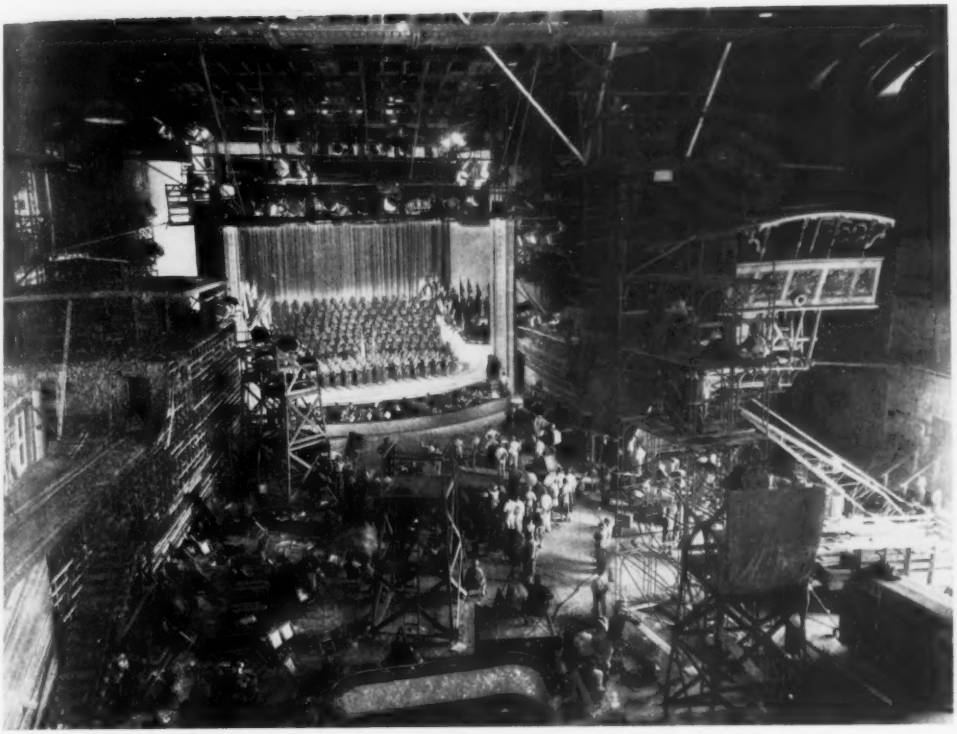
The increase in the number of studio employees due to the advent of sound was much larger than might at first be imagined. A Sound Department engaged in the operation of four fixed and two portable recording channels and in maintenance of the recording and theater equipment would require the services of approximately fifty to sixty men. Such a group would not increase the size of a studio pay roll by an appreciable percentage. However, to this number must be added the increases required in other studio departments. For example, proper control of the set lighting units during the long takes of the early sound pictures required the services of one stage electrician for each of the large lamps employed. The personnel of the studio electrical department was thereby practically doubled. The more stringent requirements on set construction made it necessary to more than double the personnel of the studio Art Department, and this in turn required corresponding increases in the number of carpenters, machinists, painters, and other craftsmen concerned with the production and erecting of set structures.

Silent pictures were generally shot with a single camera, the various camera angles necessary to secure satisfactory tempo of the finished production being secured through repeated photography of a given scene from appropriate camera positions. Until the process of dubbing sound records had received considerable development, it was necessary to secure all of the camera angles required for a scene, as well as the sound record, during a single take. The number of cameras and cameramen required for this operation was three or four times greater than that which had been required for a silent production, and the studio Camera Departments expanded correspondingly.

The need for the creation of Music Departments and Story Departments has already been noted. The labor of editing a picture was practically doubled with the introduction of sound, and the Editing Departments experienced a corresponding growth. The increased volume of film processed by the film laboratory and the requirements of accurate sensitometric control of film processing very appreciably increased the number of laboratory personnel required.

The art of process photography had been under development for some years prior to the introduction of sound but had been employed principally to secure photographic effects which could not readily be obtained by direct photography. With the introduction of sound the great increase in personnel required for production on locations stimulated the further development and application of process photography, since this technique permitted the production of scenes in the studio which could otherwise only have been obtained by transporting a full production company to distant locations. The rapid growth in the application of process photography effectively resulted in the organization of another studio department which had not previously existed.

The growth of the several departments named above was matched by a corresponding growth in the personnel of administrative, sales, publicity, and transportation departments. As the period required for the production of a sound



THE COMPLETE SOUND STAGE

SHOWING THE MODERN EQUIPMENT AND CREW NECESSARY TO SHOOT A SCENE FROM *This Is the Army*.

picture was greatly increased over that required for a corresponding silent picture, the production of a given number of feature pictures per year necessitated a large increase in the number of directors, players, and extras employed by the studio.

When all the personnel additions mentioned above are taken into account, it is found that the studio personnel increase directly attributable to the introduction of sound was of the order of 100 to 150 percent and that the cost of production was increased by 300 to 400 percent. Keeping these facts in mind and noting that the conversion from silent to sound production was scarcely completed prior to the crash of 1929, it is not surprising that many of the major motion-picture production organizations experienced the greatest difficulty in surviving the depression period.

The owners and operators of large theater chains were also confronted with a number of formidable problems during the period of conversion from silent to sound pictures. The first arose in securing a sufficient amount of theater sound equipment to permit rapid conversion from silent to sound projection; a second difficulty was presented by the problem of financing the purchase of this equipment. Sound equipment for a small- or medium-sized theater called for an expenditure of $10,000 to $20,000, while the investment required for the larger houses was in the neighborhood of $25,000. Such additional problems as were brought about through unexpired contracts for silent pictures, for large theater orchestras, for organists, and for vaudeville acts were responsible for the consumption of goodly quantities of aspirin, for few people in the theatrical

field were inclined to believe that the sound picture represented more than a passing fad.

IT NOW seems safe to predict that the sound picture will be with us for some time to come. Continued improvements in recording and reproducing equipments and in production techniques have removed practically every restriction that sound ever placed on motion picture production and have tremendously widened the scope of screen entertainment. It is no easier to predict the future developments of the sound motion picture now than it was to foresee its tremendous future in the year 1926. The value of the sound film as a medium of education has long been realized, but little has yet been accomplished in this field. The widespread use of sound-motion-picture training films during the recent wartime period is well known. Many large industrial organizations produce a number of highly specialized training films for their personnel each year, and the use of sound pictures as an advertising medium is already well established. Future generations will have available complete records of many events of historical importance in sound-motion-picture form.

Demonstrations of stereophonic sound pictures have been given a number of times in the past, and the development of equipment and techniques for the production of such pictures is proceeding at the present time, hampered somewhat from the knowledge that the investment required for new studio and theater equipment necessary for the production and showing of such films will be enormous when compared to the corresponding investment required for the introduction of the present sound picture.

The part to be played by the sound picture in the development of television is as yet unknown. Keeping in mind, however, that the motion picture provides the only means by which completely pre-edited entertainment can be provided, one would be surprised if a major portion of the best future commercial television programs was not derived from sound motion pictures produced especially for this medium.

The utilization of large quantities of narrow gauge film, particularly in the 16 mm. size, for industrial training, advertising, home entertainment, record pictures, and military applications, had led to numerous improvements in equipment and technique for the production of high quality substandard gauge sound films. The principal advantage offered by such film sizes is that of economy, for in all technical respects the quality of both picture and sound is, and must remain, inferior to that which may be derived through the use of 35 mm. film. However, the difference in costs between 16 mm. and 35 mm. professional cameras, recording equipment, processing and editing equipment, and projectors is very appreciable, as are the differences in raw film costs. The smaller bulk of a picture on substandard film sizes also offers considerable advantage when storage space and transportation costs are taken into account. It is inevitable, therefore, that such film will find increasing application. It is ideally suited to the presentation of educational subject matter and may even prove an able competitor to 35 mm. film as an entertainment medium in the smaller communities in this country and abroad.

To state that the sound motion picture has tremendous potentialities in numerous fields which have not yet been exploited is merely to state the obvious. The introduction of sound recording has transformed an entire industry; the sound motion picture can transform entire phases of our social and economic life.

SCIENCE ON THE MARCH

PHASE MICROSCOPY, ITS DEVELOPMENT AND UTILITY

THE development of the microscope into the versatile instrument it is today is high-lighted by outstanding accomplishments interspersed with periods of refinement of details and continuously extended fields of application as a result of improvements in the instrument. Many of these improvements utilize some special optical characteristics of the specimen in order to render it visible. Thus the dark-field microscope forms images by means of the light diffused by small particles. The polarizing microscope utilizes the birefringence of materials. The surface reflectance of specimens enables them to be seen by means of vertical illumination. If particles can be made to fluoresce under the action of ultraviolet radiation, the use of the fluorescence microscope is often advantageous. Direct images are also obtained by the use of ultraviolet radiation in the ultraviolet microscope and by electrons in the electron microscope, depending on the absorption characteristics of microscopic specimens for these rays.

The newly developed phase microscope promises to prove of comparable importance. In nature and industry there are many microscopic materials which are transparent or nearly so, whose details differ from their background in either refractive index or actual thickness, resulting in a difference in light path. The purpose of the phase microscope is to render such details visible with sufficient resolving power for their interpretation.

As is generally the case with scientific developments, the quest for this method has extended over considerable time. Among those whose early investigations have contributed to the development of phase microscopy are: Ernest Abbe (prior to 1892), K. Bratuscheck (1892), A. E. Conrady (1905), and J. Rheinberg (1905). It remained, however, for Professor F. Zernike, of Groningen (1935), to show that if an object is illuminated by an extended light source and this light source is focused on a diffraction plate, which must therefore be placed at the geometrical image of the light source, changes in visible contrast in the image of the object can be obtained. Using the method of Zernike, in 1941 Köhler and Loos, of the firm of Carl Zeiss, showed several applications of the method to problems in practical microscopy. Burch and Stock, of London (1942), described their results using a linear, rather than a circular, phase-accelerating element in conjunction with the microscope objective. The Spencer Phase Microscope, exhibited first in 1944 at the Cleveland meeting of the American Association for the Advancement of Science, was the result of experimental and theoretical investigations by Dr. Harold Osterberg and Dr. Helen Jupnik, physicists, Dr. Oscar W. Richards, biologist, and the writer. Subsequently, from our laboratory results have been reported by Bennett (1944), Richards (1944), Osterberg (1944), Jupnik (1944), and a more comprehensive report by Bennett, Jupnik, Osterberg, and Richards (1946). The application of this microscope to biological purposes was reported by Richards (1946).

The Spencer Phase Microscope is shown diagrammatically in Figure 1. An opaque diaphragm *D*, with a clear annular opening placed below the substage condenser *C*, at or near the front focal plane, controls the illumination. This annular stop is imaged by the substage condenser system and the microscope objective at or near the second

focal plane of the latter at *P*, where the diffraction plate is placed. The purpose of this plate is to introduce either a phase difference or an amplitude, and hence intensity, difference or both over portions of the light waves emerging from the specimen on the stage *S*. The remainder of the microscope is unchanged. Thus the annular ring diaphragm *D* and the diffraction plate *P* are the only additional equipment necessary for obtaining phase microscopy with the ordinary microscope.

The diffraction plates consist of the *B*−, *B*+, *A*−, and *A*+ types shown in Figure 1. Dielectric materials, illustrated by the half-shaded areas, are deposited by evaporation for the purpose of introducing phase differences; thin coats of metal, illustrated by the full-shaded areas, are deposited for controlling the light transmission, and hence the amplitude ratios. The annular ring on this plate is of the same size as the image of the condenser ring diaphragm. All the direct light from the specimen must, therefore, pass through the ring of the diffraction plate. Other light which has been diffracted by the structure of the specimen passes through the remainder of the diffraction plate. The plate introduces phase and intensity differences between the direct and diffracted light from the specimen, which, when combined in the image, may produce greatly increased visibility. The equipment is simple in construction and easy to use.

This form of microscopy has been found useful in the examination of objects in which the details have little or no optical contrast but differ from their surroundings only in refractive index or actual thickness, and thereby in light path. The details of such specimens can be made to appear either brighter or darker than their background. Many examples are to be found in industrial and scientific fields, such as crystals in their mother liquor, living cells, tissues, bacteria, parasites, molds, synthetic and natural fibers, emulsions, transparent replicas of surfaces, and minute surface effects on glass or plastics. Staining of specimens is unnecessary, and examination of living organisms can be made.

Figure 2 shows photomicrographs of β-naphthol crystals in brine. *A* shows that little can be seen with the ordinary bright-field microscope with the condenser stopped down to give maximum contrast in the image. *B* was taken with the Spencer Phase Microscope with a diffraction plate of the *A*+ type whose annular ring was coated with metal so as to transmit 7 percent of the direct light and with dielectric material of such thickness that the direct light is retarded by one-quarter of a wave length more

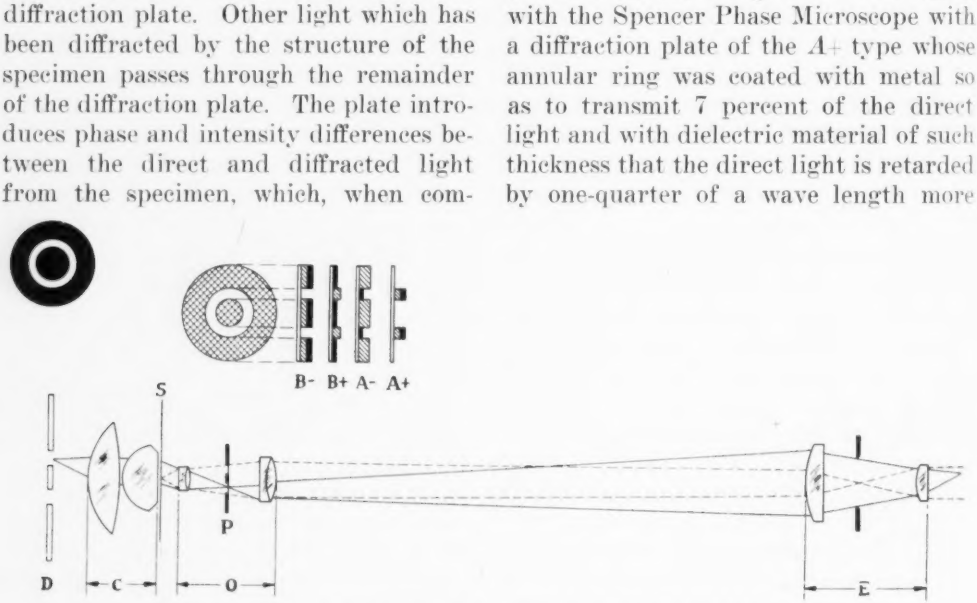


FIG. 1. OPTICAL SYSTEM OF THE PHASE MICROSCOPE

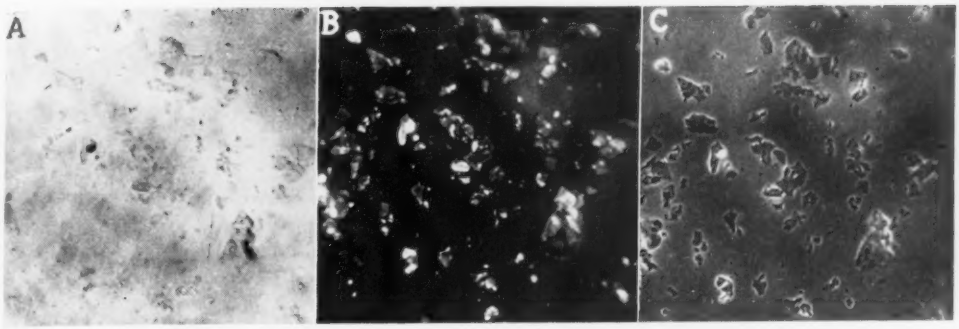


FIG. 2. PHOTOMICROGRAPHS OF β-NAPHTHOL CRYSTALS IN BRINE
A: WITH THE ORDINARY BRIGHT-FIELD MICROSCOPE; *B* AND *C*: WITH THE SPENCER PHASE MICROSCOPE. MAGNIFICATION, 213×; OBJECTIVE, 4 MM; EYEPIECE, 10×.

than is the diffracted light. *C* shows the same specimen with reversed contrast produced by use of an *A*– plate wherein the ring transmits 20 percent of the incident light but contains no dielectric material. The dielectric material is applied to the remaining portions and is of such thickness that a retardation of one-quarter of a wave length of light is obtained.

One of the important results of our investigation is that no one diffraction plate is suitable for all types of specimens. It has been found necessary to select the magnitude of the light retardation and absorption, also the type of diffraction plate—whether *A*+, *A*–, *B*+, or *B*– —(Fig. 1) in order to obtain optimum visibility for particular types of specimens.[1]

At present the range of plates necessary for a large variety of specimens has been determined as a result of experience in the examination of many kinds of material, and further investigation is in progress.

[1] In contrast to this observation, a few "phase-contrast" units made by the firm of Carl Zeiss and recently brought to this country after we had exhibited the Spencer Phase Microscope have only one diffraction plate of the *A*– type for each objective lens.

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THE VOYAGE OF THE *CHALLENGER*

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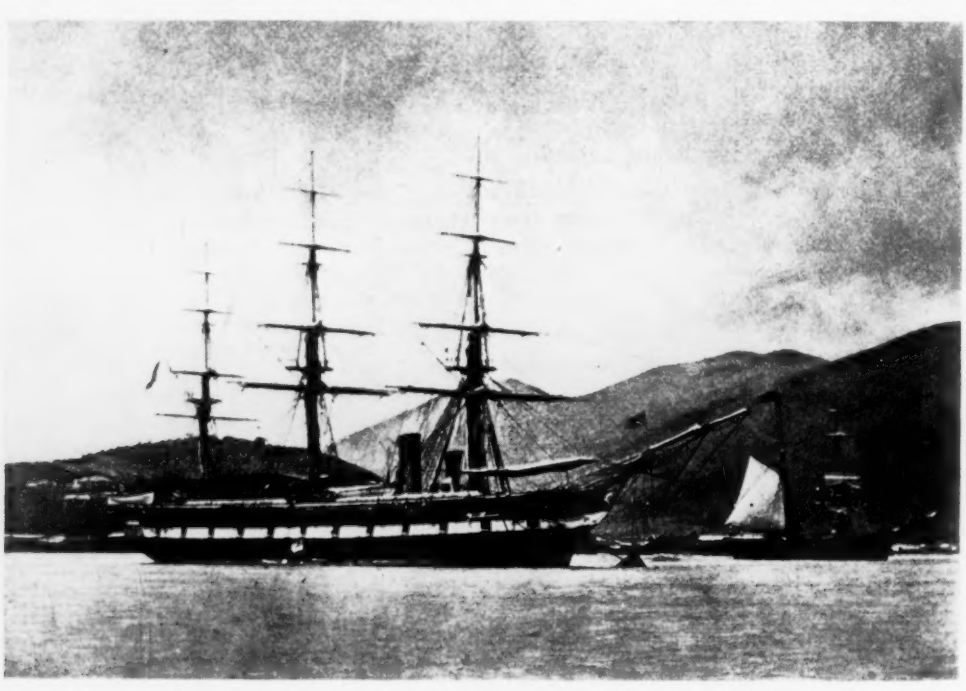
SEVENTY years ago, on May 24, 1876, a seaworn British man-of-war, disarmed and laden with a most unwarlike cargo of mud samples and pickled specimens of creatures from the ocean depths, dropped anchor at Spithead after a three-and-a-half year absence from England. Thus, without fanfare or cheering crowds, H.M.S. *Challenger* came home, and with the completion of her peaceful voyage of 68,890 nautical miles the new science of oceanography was well begun. It was a long and adventurous voyage, which more than fulfilled the expectations of those who had planned it, although it upset some of their favorite theories about the active formation of chalk on the ocean bottom and the occurrence of the primordial stuff of life in the depths. The voyage also established the reputations of several young gentlemen who had shipped on as naturalists at a salary of £200 per annum, and it nearly bored many of the naval staff to tears long before it was over.

It has been said that the primary motivation of the *Challenger* Expedition was the hope of proving the "continuity of the chalk" and the prevalence of bathybius, but the expedition was planned on such a broad and inclusive scale that the refutation of these popular theories early in the voyage had little effect on its course. The credit for conceiving and instigating the *Challenger* Expedition belongs to Professor Wm. B. Carpenter,



H.M.S. *CHALLENGER*, ST. THOMAS, W. I., MARCH 1873

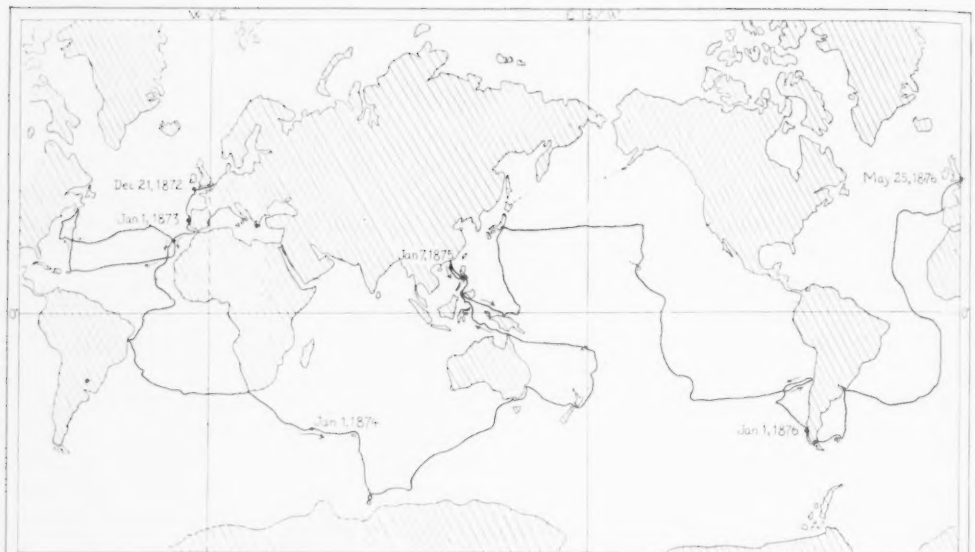
of the University of London, and Professor Charles Wyville Thomson, of Edinburgh. Convinced of the need and value of deep-sea exploration by their preliminary dredging work around the British Isles on H.M.S. *Lightning* in 1868 and H.M.S. *Porcupine* in 1869 and 1870, they decided that the time had come to undertake a more extensive expedition. Evidently many others were of the same opinion, even in naval circles, for Carpenter's preliminary correspondence with the Admiralty on the proposed deep-sea exploring expedition early in 1871 was favorably received.

The Admiralty waited only upon a formal request from the Royal Society, and by the closing months of 1871 a committee of the Society had been set up, and the plans for the "voyage of circumnavigation" were well under way. This committee included, in addition to Carpenter and Thomson, Professor T. H. Huxley, who played an important part in drawing up the research program for the voyage; Mr. Gwynn Jeffreys, an enthusiastic conchologist who was to become the father-in-law of Moseley, one of the young naturalists who made the voyage; Mr. Alfred Russell Wallace; and several other eminent men of British science. Indeed, one misses only the name of Darwin from this committee. By the end of June 1872 the Admiralty had commissioned the *Challenger*, a steam corvette of 2,306 tons, for the voyage, and lost little time after that in refitting her according to the suggestions of the committee of the Royal Society.

The *Challenger,* up to the time of her commissioning as a research vessel, did not have a particularly distinguished record. She was built at Woolwich and launched on February 13, 1858. In 1860 the *Challenger* was sent to Mexico and occupied Vera Cruz in an effort to collect indemnities due British citizens but withdrew without gaining any settlement. Later the ship was sent to Australia and in August 1868 shelled Rewa in the Fiji Islands in retaliation for the murder of a missionary and some of his dependents. Some boats were also sent ashore. As a result of this action, "some natives were killed," and when the *Challenger* returned to the Fijis on the peaceful business of science many of the natives took to the woods. The ship's career after the completion of the cruise was even less distinguished: she was cut down as a barge and remained in this humble service until 1921.

While the *Challenger* was being refitted, the scientific staff for the expedition was appointed, with Wyville Thomson as director. Although he was reluctant to accept this post, which he believed more suitable for a younger man, he agreed to direct the cruise. As it turned out, the long voyage impaired his health, and he did not live to see the reports of the expedition completed or to write a book on the Pacific which he had planned to complement his preliminary volumes on the Atlantic. John James Wild, a Swiss artist, was appointed artist and secretary to the director. The remainder of the staff, as originally appointed, consisted of J. Y. Buchanan as chemist and physicist and H. N. Moseley, William Stirling, and John Murray as naturalists. Before the cruise began, Stirling resigned, and Rudolf von Willemoes-Suhm, *Privatdocent* in Zoology, of the University of Munich, was appointed. The most important position of captain of the ship was given to Captain G. S. Nares, an experienced survey officer.

At last the lengthy preparations were completed, the supplies aboard, and the expedition was ready to start upon its four-year course. There had been much publicity in the press, including that inimitable journal *Punch*, which dedicated its December 28 number to the *Challenger*, admonishing the voyagers to read "the whale, by Herman Melville." There had been some questions



TRACK OF H.M.S. *CHALLENGER*, 1872–1876

raised in Parliament, but on being assured that the cost of the expedition would be "no more" than that of keeping the vessel in commission, Parliament approved the funds. "Thus, with every possible advantage, and in the highest hope of being able to fulfill her difficult mission, the *Challenger* cast off from the jetty at Portsmouth at 11:30 A.M. on Saturday, the 21st of December, 1872." The last man aboard was a young navigating sublieutenant, Herbert Swire, who was to be the last survivor of the expedition and the author of its most readable journal.

No better idea of the men who were to be messmates and fellow-adventurers in science for nearly four years can be had than from Lieutenant Swire's journal, as he met them for the first time on board the *Challenger:*

> Our civilian scientific staff, on the whole, have turned out pretty good sailors, especially one of them, who has just returned from a "pleasure trip" in a North Sea whaler! . . .
>
> First, then, as head of the civilian staff, we have Professor Thomson, or, rather, Wyville Thomson. He gave up an appointment worth some £2,000 a year to join this ship, where he gets only half that sum, but will doubtless have the satisfaction of placing his name on the roll of fame with those of eminent scientific men who have gone before him. The professor is a stoutish man and has not yet got over his seasickness, so I know little or nothing of him personally. Then there is Murray, naturalist, I think, who is the sailor-like individual before mentioned; Buchanan, whose strong point in science I have not yet discovered . . . ; von Suhm, a botanist and a Dane or German, and decent sort of fellow to boot, and the youngest of the "philosophers," as we call them; Wild, artist and Swiss, who is very dyspeptic and seldom to be observed by the eye *vulgarus;* Moseley, naturalist, and chockfull of science, even unto bursting.
>
> Now of our own people, the first is Captain Nares, who is generally considered to be a devilish good fellow and one of the best captains in H.M.'s Service; he has served in all parts of the world, including the Arctic regions, where he went with the Franklin search expedition. In personal appearance he reminds me intensely of the faces of Elizabeth's reign, Shakespeare, Raleigh, or some such countenance, or perhaps it is Charles I that his face calls up; at any rate there he is, pointed beard, high bald forehead, and head with a full round top: a clever man by the shape of his head, most people would say. Next comes Commander Maclear, who is second in command, and also has charge

of the magnetic department of the expedition, and seems to be a good fellow; in fact, to save time I will at once state as a fact beyond dispute, that we are all good fellows, every one of us.

Among the other members of the naval staff was the son of the Duke of Argyll, Lord George Campbell, who was to write a popular journal of the cruise that went through several editions. He brought along his Newfoundland dog, which was not the least of the *Challenger's* complement of livestock. In fact, the *Challenger* was equipped with a miniature barnyard on the main deck, including "at least twenty ducks, fifty hens and cocks, several geese, and about fifteen sheep." There was also a small garden. Moseley, in his journal, devoted a page or two to an account of the fauna acquired by the ship on her voyage: the unwelcome rats and cockroaches; the spiders, invited aboard by the surveyors, who used their webs in their instruments; and the two parrots purchased by himself and von Suhm. One of the parrots met an untimely end in a pan of hot caustic potash, but the other, named Robert, survived the trip and learned to say as the dredge came up: "What! Two thousand fathoms and no bottom! Ah, Dr. Carpenter, F.R.S."

From the vantage point of seventy years it would seem that all the *Challenger* lacked was a musical score by Sir Arthur Sullivan. Certainly W. S. Gilbert could not have picked a more typically English crew, with the added touch of a foreign naturalist. It is possible that some of the members of the scientific staff realized this, for they cheerfully accepted the familiar label of "philosophers." But it was to be a long, hard cruise, and the young German naturalist was never to see his native land again. Of the 243 men who left with the *Challenger,* 144 returned. Of the original crew, 61 deserted the ship, which indicates that life aboard one of Her Majesty's ships in those days did not appeal to many of the common sailors.

The Channel in December was rough beginning for the voyage, and it was not until December 30 that the first sounding was taken. Then, in Latitude 41° 57′ N., Longitude 9° 42′ W., at a depth of 1,125 fathoms, the dredge was lowered for the first time. The first try was unsuccessful because of the high sea, but on the second attempt a load of mud and a few creatures, including a handsome starfish, were brought up. Champagne was chilled in a tubful of icy ooze brought up by the dredge, and the success of the expedition was drunk. It was not until February 15, 1873, however, that the first official station was taken, at 27° 24′ N., 16° 58′ W., in 1,890 fathoms, about 40 miles south of Teneriffe. This, according to J. Y. Buchanan, was the birthday of oceanography.

ALTHOUGH the original itinerary of the *Challenger* included a more extensive exploration of the South Atlantic than was actually undertaken and a line across the North Pacific to Vancouver which was evidently cancelled because of the transfer of Captain Nares at Hongkong to an arctic expedition, the *Challenger's* voyage still stands as the longest continuous exploration by a scientific vessel. Ships like the *Albatross* and the *Carnegie* logged more miles, but their careers included several separate voyages. Many of the gaps left by the *Challenger* on her pioneer voyage have since been filled by other vessels, but it can still be said that the ocean is but partly explored. There are vast areas in the South Pacific and Indian Ocean which have yet to be sounded—even in these days of rapid sounding methods—let alone sampled for their fauna and tested for their physical and chemical characteristics. The *Challenger* had planned to make a complete station at regular intervals around the globe, but circum-

stances did not always permit this; the total number of official stations was 362.

When the *Challenger* began to dredge, even the deckhands were curious, but as the years wore on fewer and fewer members of the staff remained on hand when the dredge was brought aboard, until at the end only the indefatigable Wyville Thomson remained for a first glance at the booty. It became a tedious chore for the naval staff, and a water haul was often a source of argument as to whether the dredge had actually reached the bottom. When it is remembered what a difficult and dangerous operation deep-sea dredging was seventy years ago, it is remarkable that only one man was killed by a failure of the tackle. Indeed, the loss of equipment during the long voyage was a record any modern vessel might be proud of: although Buchanan's summary of the loss of thermometers is confusing, since his total of 13 thermometers lost does not tally with his itemized list of 19 carried away and the added loss of "two temperature lines . . . with eight thermometers" and still another loss mentioned later. At any rate, it appears that the *Challenger* lost at most 28 thermometers during soundings. According to the official summary, 48 thermometers were expended altogether. The dredging operation was even more successful, for the tackle broke but eleven times during the voyage, leaving a dredge or trawl on the bottom. This record is especially remarkable when it is remembered that hempen sounding and dredging lines were used throughout the voyage and that dredging was a tedious business.

An idea of how tedious it was for those not particularly interested in science can be had from Lord Campbell's *Log Letters:*

> Dredging, I may say without fear of contradiction, was our—the naval officers'—*bête noir*. The romance of deep-water trawling or dredging in the *Challenger*, when repeated several hundred times, was regarded from two points of view; the one was the naval officer's, who had to stand for ten or twelve hours at a stretch carrying on the work, and who, always excepting that he did not like his day's work to have been done in vain, did not know much about, or *scientifically* appreciate, the minute differences between one starfish, one shrimp, one sea-cucumber, one sea-urchin, and another. The other point of view was the naturalist's, to whom the whole cruise was a yachting expedition, who had not to carry on the practical working of the dredge, to whom some new worm, coral, or echinoderm is a joy forever, who retires to a comfortable cabin to describe with enthusiasm this new animal, which we, without much enthusiasm, and with much weariness of spirit, to the rumbling tune of the donkey-engine only, had dragged up for him from the bottom of the sea.

Probably some of the young lord's shipmates, when they read these words, thought he was putting on just a little, for Lord Campbell apparently never missed a shore leave and was evidently the ship's most indefatigable excursionist. Lieutenant Swire, who wrote a better journal, was less fortunate. As a member of the surveying staff, he had to spend much of his time ashore on unexplored islands at his instruments while Lord Campbell and the naturalists ranged gaily over the terrain. He also became heartily sick of the dredging and wished for an end to it before the first year of the voyage was out. Another tedious job aboard the *Challenger* was that of the chemist, although that individual left no journal with passages of lamentation about his unhappy lot.

The chemist of the *Challenger* will always be remembered for his bursting of the "bubble of Bathybius." This fabulous substance had been discovered in bottom samples secured on telegraph cable surveys and appeared to be some sort of life. Huxley considered it some sort of amoeba and named it after his colleague Haeckel, and Haeckel considered it the mother of protoplasm. It proved very elusive to the naturalists of the *Challenger*, although they sought it diligently. Buchanan, however, was a chemist, and as such he "looked at the

matter from a different point of view from that of the naturalists." Failing to find a trace of organic matter by analysis of the several specimens finally caught by John Murray, Buchanan suspected its inorganic nature and demonstrated that bathybius was nothing but an amorphous precipitate of sulphate of lime in spirits of wine and sea water.

Thus a great scientific idea came to an ignominious end. Graciously conceding that bathybius had been of some use, Buchanan declared in his report that it "should not be allowed to pass into oblivion." Indeed it should not, for science should remember its errors perhaps even more carefully than its successes. Although the *Challenger's* philosophers laid bathybius low, they were not immune from mistakes of their own, as Swire relates in his *Journal:*

> A wonderful new piece of clayey substance turned up in the analysing room, of whitish colour and having many remarkable peculiarities. It was found amongst specimens of the soils, etc., composing the islands of Bermuda, and as this particular substance had evidently not before been noticed by geologists and others as belonging to the Bermuda formation, the philosophers sat in solemn conclave, made an elaborate analysis of the strange stuff and sent home to England accounts of their great discovery. They were well satisfied with what they had done till, alas, one day a marine, prowling round the analysing room saw lying on the table an article which he at once recognized as a missing piece of pipeclay, his property, and took it away with him. No sooner did the philosophers miss the valuable substance which they had so long been puzzling over than they raised the hue and cry, when the story of course came out, and loud was, and is, the laugh against our learned men for this unaccountable blunder.

Achievements far outweighed blunders, however. In addition to settling the fate of bathybius, the *Challenger's* investigations included the first comprehensive analyses of the ocean bottom, demonstrating incidentally that chalk was not being laid down on the ocean floor by the shells of marine organisms. The pelagic character of many of the minute organisms of the sea, whose shells had been known only from bottom samples, was proved, and the fauna of the great depths was collected for the first time. Many had hoped for living fossils from the deep dredgings, but none was discovered, and the essentially contemporaneous character of deep-sea life with that of the shore and shallow sea soon was determined. The incidental fact that no traces of Atlantis were found did not discourage the ardent believers in that old tale of Plato's—mere negative evidence has never discouraged an antediluvian.

The sea-water determinations based on *Challenger* samples were so accurate that subsequent analyses have caused only minor corrections, and it can be said that the chemical nature of sea water was definitely established on this voyage. Many of the *Challenger's* most important results were published in British journals during the cruise. One of these reports prompted a humorous bit of doggerel in *Punch;* another, on preliminary temperatures, was the cause of an accusation against the scientific staff. W. L. Jordan, author of a semipopular treatise on hydrography and oceanography and possibly somewhat jealous of his colleagues, believed that the revised temperatures, based on later computations, were deliberate attempts to fit facts to preconceived notions and published a thirty-five page pamphlet to prove his case. It is true that the *Challenger's* thermometers were not as precise as those used today, but subsequent researches have supported the essential accuracy of the *Challenger's* temperatures, and Jordan's pamphlet is little more than a curiosity.

An unanticipated result of the voyage was the series of journals by various members of the expedition, which are useful sources of information about native life and manners on Pacific islands

and places which have changed beyond recognition in the seventy years since the *Challenger* visited them. All these journals were written during the cruise, but one of them was not published until 1938, when Herbert Swire's journal was handsomely printed by the Golden Cockerel Press at a de luxe price which has kept it out of reach of those who can best appreciate it. The journals by Moseley and Campbell, published shortly after the voyage, ran through several editions, and Moseley's book, stuffed with natural history and anthropology, is still kept in print, a standard item for libraries of scientific travel and exploration.

For such a long cruise, the *Challenger's* was comparatively uneventful: on the whole, it was a placid plodding around the world under sail (steam was used only for dredging and emergencies) at the leisurely speed of eight or ten knots. There was a close shave during a dangerous night on the edge of the antarctic ice and an unpleasant hour or two off Tierra del Fuego when the anchor struck a rock and broke, leaving the ship to drift toward a lee shore, and there were a few close calls with uncharted reefs, but that was all. The old reconverted warrior, with all her gunports, proved an unexpectedly comfortable and airy ship. Ten of the *Challenger's* original company of 243 died during the voyage, including a man lost overboard. Although rescued, he died shortly after. His rescuer, who had dived over after him as soon as the cry of "man overboard" was raised, was awarded the Albert Medal for his "most gallant action."

The most serious loss in the ship's company was the death from erysipelas of the young German naturalist von Willemoes-Suhm shortly after the ship left Hawaii. In the light of the subsequent careers of the rest of the *Challenger's* scientific staff, it is safe to say that von Willemoes-Suhm's name would have been eminent in zoology had he survived. Moseley became a well-known zoologist, one of the founders of the Marine Biological Association of the United Kingdom, teacher of several fine students of coelenterates, and the father of England's most brilliant physicist, whose death at Gallipoli was one of science' most grievous losses. Buchanan became oceanographer for the Prince of Monaco, while Murray's name became virtually synonymous with oceanography itself, and his researches earned him a knighthood.

WITH the completion of the voyage, the *Challenger's* work was just begun. The collections of plants and animals had to be sorted and sent to specialists, the chemical and physical data had to be checked and analyzed, and the reports seen through the press. The collections were deposited in the University of Edinburgh, and John Murray remained as Wyville Thomson's assistant to handle the material. When Thomson died in 1882, Murray fell heir to the *Challenger* material, and today it is his name which is remembered in connection with the voyage.

There is some justice in this, for, without Murray's personal fortune and unflagging interest in oceanography, the complete *Challenger* reports might never have been published. Murray financed many of the fifty folio volumes, which are the *Challenger's* monument, from the income derived from the development of the phosphate resources of Christmas Island in the Indian Ocean. He often said that the revenue to the Crown from this development, which was a by-product of his studies of ocean deposits, alone paid for the *Challenger* Expedition. Written by the authorities of the day, many of the *Challenger* reports are still the indispensable starting points for the study of marine life. This is especially true of zoology since so many new spe-

cies were brought up by the *Challenger*. There were other difficulties beside financial ones involved in the publication of the *Challenger* reports. An especially notable one is best appreciated from an explanatory slip which is attached to the title page of one of the volumes:

> This is one of the copies referred to in the following Extract from the Third Report of the Controller of Her Majesty's Stationery Office, presented to Parliament in 1890:—
>
> The publication of the reports, by no means all of which, as your Lordships will recollect, were prepared in Great Britain or Ireland, has gone on without any mishap until a few months ago, when, unfortunately, a steamer carrying from Leith to London 30ó copies of a volume then lately issued, was run into and sunk off the Lincolnshire coast. Among the damaged cargo afterwards recovered from the wreck and sold by auction by direction of the honourable Corporation of Trinity House, under the Removal of Wrecks Acts, 1877, were 13 cases containing about 190 of the lost "Challenger" volumes, in a more or less spongy state. These were bought back by the Stationery Office. They have since been taken out of the covers and dried, and it seems probable that from them, with the addition of new copies of some of the plates which happen still to remain on the stone, about 100 copies may be made up, stained, but for all practical purposes perfect. The copies thus made up will not, unless specially asked for, be issued for sale until the uninjured stock of the volume is exhausted. It is not impossible that in the eyes of future owners the imperfections of the recovered volumes may be compensated for by the knowledge that the books, like the "Alcyonaria" and "Polyzoa," which are beautifully figured in them, have been drawn from the bottom of the sea.

Their pages still taste of salt.

Finally, in 1895, nineteen years after the end of the voyage, the *Challenger Reports* were completed. The complete set of fifty volumes has since become a model for expedition reports, although few have equalled the *Challenger's* series in range of subject matter or completeness. There are volumes on zoology, botany, hydrography, bottom deposits, and the history of oceanographic research up to the time of the *Challenger* Expedition; and on that long row of big green volumes is based the modern science of oceanography. Their completion was just cause for celebration, and in commemoration of the event John Murray had a medal struck off and presented to each contributor; the contributors made up an album of their photographs for Murray, which was later published in facsimile as a souvenir.

Seven hundred and fifty sets of the reports were published. Today the sets repose in libraries all over the world, a constantly consulted monument to a great enterprise. As for the ship herself, she was decommissioned and turned into a coal barge. But the completion of the reports and dispersal of the scientific staff was not the end of the *Challenger* as a name in oceanography. Today much of the original collections, together with John Murray's library, is in the custody of the Challenger Society at the British Museum, which plays a leading part in directing oceanographic work in Great Britain.

Even in the *Challenger's* day, before the cruise was completed, other nations realized the importance of scientific research on the high seas, and several expeditions were fitted out. The *Challenger* had hardly begun her cruise before the Germans sent out the *Gazelle* for a two-year cruise. A few months after the *Challenger* returned, Alexander Agassiz began his active career in oceanography by directing the first cruise of the *Blake* in the waters of the Caribbean and Gulf of Mexico, and the Norwegians commenced their North Atlantic investigations in the *Vöringen*.

Still, after seventy years of deep-sea research, we have only made a beginning, and knowledge of the ocean, its life and physical characteristics, is more useful than ever. The war brought this out in many ways, for the Navy was confronted with problems as diverse as the effects of currents on life rafts in midocean and

the sounds made by fish and shrimp in submarine-detection devices. It is safe to say that the study of the oceans will be intensified in the next few years, for several governments are already planning investigations. The Danes have a ship ready for work off the African coast, and the U. S. Navy has just established a Division of Oceanography in its Hydrographic Office. Perhaps there will never be another such expedition as that of the *Challenger*, with her crew weighing anchor the first thing in the fresh morning of a new science. But the age-old challenge of the deep, which has stirred men of curiosity since the beginning of time, is still as strong as ever, and men still sail out to meet it. Certainly no research vessel can have a better name, and few can hope to gain as important a place in the history of science as did Her Majesty's Ship *Challenger*.

Sources of Information

In all, seven journals by members of the *Challenger's* company were printed, one of them as late as 1938, and another was reprinted in 1944. These and other items of interest (exclusive of the *Narrative of the Cruise* and *Summary of Results* in the *Challenger Reports*) are as follows:

Buchanan, J. Y.

"A Retrospect of Oceanography in the Twenty Years Before 1895." Address to the oceanographical section of the Sixth International Geographical Congress, held in London, 1895; revised and amplified. No. 2 in *Accounts Rendered.* Cambridge; pp. 28–86. 1919.

Campbell, Lord George

Log-Letters from "The Challenger." London: Macmillan & Co. 512 pp. 1877.

Jordan, W. L.

The Admiralty Falsification of the "Challenger" Record. Exposed by William Leighton Jordan, &c. London: Spottiswoode & Co. 35 pp., chart. 1890.

Moseley, H. N.

Notes by a Naturalist. An account of observations made during the voyage of *H.M.S. Challenger,* &c. A new and revised edition, with map, portrait, and woodcuts and a brief memoir of the author. London: John Murray. xxiv + 517 pp. 1892. (Reprinted by Laurie, London. 540 pp. Illus. 1944.)

Spry, W. J. J.

The Cruise of Her Majesty's Ship "Challenger." Voyages over many seas, scenes in many lands. New York: Harper & Bros. xvii + 388 pp. 1877.

Swire, Herbert

The Voyage of the Challenger. A personal narrative of the historic circumnavigation of the globe in the years 1872–76 by Navigating Sublieutenant Herbert Swire, R.N. Illustrated with reproductions from paintings and drawings in his journals. Foreword by Major Roger Swire, R.C.R.E. Introduction by G. Herbert Fowler, C.B.E. London: Golden Cockerel Press. 2 vols., folio. 1938.

Thomson, C. Wyville

The Atlantic. A preliminary account of the general results of the exploring voyage of H.M.S. "Challenger" during the year 1876. New York: Harper & Bros. 2 vols. 1878.

Wild, J. J.

At Anchor: a Narrative of Experiences Afloat and Ashore During the Voyage of H.M.S. "Challenger" from 1872–67. London and Belfast: M. Ward & Co. 198 pp., 13 col. plates. 1878.

Willemoes-Suhm, Rudolf von

Challenger Briefe. Leipzig: Verlag von Wilhelm Engelman. xii + 180 pp. 1877.

THE LAST CANUTE

By GARRETT HARDIN
SCIENCE DEPARTMENT, SANTA BARBARA COLLEGE

The editors of the MARTIAN MORNING REVELATION are proud to present to their readers another exclusive REVELATION revelation. The following document was found engraved on stainless steel plates which have only recently been uncovered near the site of Worldly New York. With the discovery of these plates we have, for the first time, found evidence that at least a few Worldlings tried to fend off their doom. . . . What a strange quirk of Fate that these people, who titillated themselves with visions of catastrophic destruction by atomic power —which to these primitive folk seemed a wondrous thing—should instead have perished peacefully, inexorably "suffocated," as one of their prophets put it, "by their own intellectual excreta."

Last Meeting of the Board of Trustees of the New Alexandrine Library Fund

January 20, 1955, at 1500.

THE meeting was opened by Mr. Gregory Adams, Chairman. The minutes of the previous meeting were read and approved. The treasurer's report was read and approved. There being no further routine business, the chairman proceeded to a summing up of our activities.

Mr. Adams. Gentlemen, this is a melancholy occasion. We are gathered today, only a little more than two years after the beginning, to give the *coup de grâce* to the New Alexandrine Library Fund. The aims of Mr. Babcock, the founder, have not only not been carried out, they have been completely thwarted. Eighty million dollars thrown to the winds! Think of it, gentlemen.

It seems to me that we ought to have a ceremony of some sort, but I don't know exactly what. You lay a cornerstone when you begin a building, cut a string when you open a road. But what do you do when you bury a dream? What sort of ceremony is appropriate?

Perhaps the most suitable thing we can do is make the minutes of this, our last meeting, a sort of memorial to this dream. With that thought, I should like to read into the minutes a brief résumé of the life and death of the New Alexandrine Fund. You all know it as well as I, but if you will bear with me—perhaps correct me and add to the record——. It will be a sort of wake——.

Just exactly where one should begin the story of Chauncey Babcock and his dream I'm not sure, but I believe it began about ten years ago when the librarian of one of the small Eastern colleges wrote a book in which, among other things, he pointed out that at the present rate of growth the Yale library, as an example, will, in the year 2040, contain two hundred million volumes occupying six thousand miles of shelves and will require a staff of six thousand librarians to do the cataloguing alone. I believe those were the figures. At any rate, the author proposed as a solution to this problem that libraries should change from full-size books to microbooks, books photographically reduced to a fraction of their original size. Similar proposals, differing only in details, were made by other scholars and scientists, some of them proposing perfectly fantastic gadgets for housing and using microfilm. It was thought that since microfilm took up so little space, the whole storage problem would vanish.

It was at this point that Mr. Babcock became interested in the problem, and, although he was a businessman rather than a scholar, his native common sense permitted him to see the fallacy of the proposed solutions. Simply stated it is this: you cannot by any means of compression solve the problem of storing a pile of documents which is growing without limit. You can merely delay the day when the problem becomes spatially embarrassing. Instead of that day coming in two centuries, it may come in two millennia. But ultimately the day of reckoning must come.

To suppose otherwise is absurd, as though

one supposed that since mice—to take an example—are individually very small animals they will never take up much space no matter how much they reproduce. But we all know that any organism, no matter how small, will finally occupy the entire universe if it continues to multiply unchecked. In the long run, it isn't the size of the individual that is important; it is the growth rate of the population. In nature, the fecundity of plants and animals is opposed by various causes of mortality, so that the net growth rate of most populations at most times is zero. In man's libraries, on the other hand, there is a quite different situation. Here, apparently, there is no death, only birth. The number of library books doubles six times a century. How big those books are is a matter of only evanescent importance.

Mr. Babcock realized that no real beginning can be made in the solution of the problem until librarians begin to destroy their books. Libraries must have a well-thought-out system for getting rid of books, as they have for acquiring them. This seems obvious enough—to everyone but a librarian. His profession is getting and keeping books, storing them and holding them. As a result he has, with very few exceptions, the magpie's instinct developed to an exceptional degree. Whether the profession tends to select the person who has this hypertrophied instinct in the first place or to develop it in him after he enters the ranks, I don't know. Probably a bit of both. The end product is the same: a magpie, a pack rat. So strong is his impulsion to collect that one cannot even discuss with him the possibility of un-collecting and expect to receive a rational answer. Consider yourself lucky if your suggestion evokes nothing more violent than the cold, glassy stare of the outraged professional man.

Plainly, some books and documents must be destroyed. But how persuade librarians of this? That was the problem Mr. Babcock faced. Weeding out had been proposed by laymen a good many times, but the proposal always met with the most bitter scorn. What was needed was some way to force or persuade the librarians to accept it. Mr. Babcock's great contribution to learning and civilization was the discovery of a way. That it failed is almost incidental. It was a good idea. If the loopholes are plugged I think it may yet work, if given another chance.

Between 1945 and 1951, when he wrote his will, Mr. Babcock did a good deal of snooping around libraries, investigating librarians, and questioning the users of libraries. Talks with scientists revealed one curious aspect of libraries, namely, that the more worthless books become for the scientist, the more valuable they are in the eyes of the librarian. Take, for instance, the field of genetics. Before Mendel, there were veritable libraries of books on heredity—Gaertner, Koelliker, Naudin, Koelreuter, to mention only a few of the scores of authors. Yet with the publication of Mendel's forty-page paper all these other tens of thousands of pages became utterly useless. Today, no one who wished to learn the facts of heredity would dream of consulting Gaertner or Koelreuter. As a matter of fact, he wouldn't even look up Mendel's obscure paper, for the essence of its forty pages can, without loss, be neatly stated in two. Yet, do the libraries throw away any of their copies of Gaertner and Koelreuter? On the contrary! Any "normal" librarian would trade a hundred books of 1955 science for one musty, useless volume written by Gaertner and consider that he'd made a fine bargain. Librarians often justify the size of their elephantine institutions by pointing to the ever-increasing growth of science and of scientific publications which they must store. But science, ever-expanding though it is, is at the same time ever-contracting. It requires the expenditure of years of work and the publication of thousands of scientific papers to arrive at a single great generalization. When you look at the situation from the other end, you see that each great generalization makes obsolete and valueless tons of research reports that were spewed forth on the way. Scientists are aware of this fact; librarians seem not to have been informed of it.

Rambles through library stacks led Mr. Babcock to another discovery. He found that, quite aside from "source" works, for whose preservation there are ready-made rationalizations, there is a much larger mountain of derivative works—textbooks and like compendia—for which there is no excuse other than timeliness. Mr. Babcock was struck with the spectacle of the tons of old textbooks that clutter up libraries quite uselessly. Take down any student text dated 1900 and you will likely discover from its

record sheet that, although it was much used for the first five years, it was last drawn out about 1910. It has been sitting idle on the shelf for the past forty-five years and bids fair to be sitting there still on Resurrection Day, barring termites, fire, floods, earthquakes, and bombings.

Mr. Calhoun. Incidentally, the mention of termites reminds me of a story which none of you, I believe, except Mr. Adams has heard before. It was told to me by Mr. Babcock not long before his death. It seems that one day, permit in hand, he was browsing around in the basement of the main library of the University of Chicago when he discovered a young man pulling away some rotten wood from an old and much-patched wall. Mr. Babcock became curious and asked the fellow what he was doing. He turned around and looked Mr. Babcock squarely in the face for perhaps five seconds, thus assuring himself that his interrogator did not have the physical conformation of a librarian, then explained: "I'm taking some of this wood for use in a zoology course. You see, there's a good termite colony here, and we need termites to illustrate Serial Homology and Convergent Evolution. We get them from here every year."

"But," said Mr. Babcock, "doesn't the library know about this? These termites could do a lot of damage, couldn't they?"

"I don't think so. It's too far north for them to really thrive. At any rate, when I'm through I'll put in a new board where I took out the old one so as to keep the colony going. If you'll notice," he said, pointing to the variegated wall, "this has been going on for a good many years, and they don't seem to have started on the books yet. It's an unwritten rule that each new zoology assistant shall show his appreciation to the Harper termites by putting in a new piece of wood and will not tell the librarian about the colony. We hope that you, too, will respect the tradition, sir."

Mr. Adams. Yes, that's right. I might add that Mr. Babcock even toyed with the idea of establishing an eighty-million-dollar termite hatchery, but gave it up on advice of a distinguished termitologist.

(Laughter.)

And that brings us to another, and perhaps the most curious element of the whole library picture, namely, the librarian. As I have intimated, years of tending books have made him more interested in the conservation of knowledge than in its dissemination. Discovery of this truth was quite a shock to Mr. Babcock, who had innocently supposed the contrary. He found, for instance, that librarians are pretty generally opposed to replacing books that are stolen, on the curious ground that the replacements will likely be stolen, too. They tend, though perhaps unconsciously, to buy unpopular books for this reason, though they never call them unpopular, of course; they call them "scholarly." As you can see, if popular books are stolen and not replaced, and unpopular ones are left unmolested on the shelves, the result is natural selection working in favor of the worst books. In relative terms, as the library gets older and bigger, it gets worse and worse. But no librarian will consider remedial measures.

Mr. Falconer. I think you do librarians some injustice there. Admittedly, many of them are simply bibliophilic pack rats, but there is an appreciable minority that is quite aware of what's going on. Suppose a librarian decides to weed out the deadwood, how is he to do it? Is *he* to take the responsibility alone? After all, each field requires its own experts to do the judging. What is needed is better liaison between the library and the rest of the departments. Some small institutions actually have a weeding-out system. The situation is usually worst in the larger places where the departmental walls are highest and the art of evading responsibility developed to the highest degree. The librarian in a large institution may be quite amenable to the idea of a book-purge, but he can find no one to take the responsibility of naming the books.

Mr. Adams. I think there is some truth in what you say. Perhaps it is not men but the system that is at fault. Whatever the cause, Mr. Babcock proposed to use his money to try to remedy the situation. He knew that a mere eighty million dollars wasn't much, but he thought an humble beginning might be made, that a little money properly spent might have an immense moral effect. Hence the terms of his now famous will: Twenty million dollars available to the libraries of Harvard, Columbia, Chicago, and Stanford, on condition that for each $10.00 they applied for, one book of at least five hundred

pages must be removed forever from the stacks and destroyed. Yale University was also originally scheduled for a share of the Fund, but in the end it was decided to keep the Yale library as a control.

Of course, there had to be a lot of legally complicated conditions designed to prevent the libraries' acquiring duplicates of the very books discarded, which they might very well do, for librarians have collectors' morals. But the mechanics of selecting the books to be discarded were left to the discretion of the beneficiaries.

Well, we know the reaction when Mr. Babcock died and the terms of the will became known. The four great universities simply exploded. On the one hand, there was pressure from the alumni and the trustees to accept the money, and on the other there was the hysterical refusal of librarians to commit such an unnatural crime. Cries of rape and pandering, sacrilege and desecration, filled the air. There were threats of resignation and counterthreats of acceptance. One library employee actually did resign—he was a fifteen-dollar-a-week stack-boy at Harvard, who did so at the request of the head librarian. It was intended as a show of force. The example was not followed by others.

Finally, at Stanford, where the need for funds was most desperate, there came an offer of arbitration. They announced that they were willing to live up to the terms of the Fund, provided the provisions were made more generous. Whereas, they said, it cost $1.23 to accession an incoming volume, they estimated it would be impossible to remove a book for less than ten times that amount, on account of the clerical problem of rooting out all the cross-index entries, etc. We felt that their accounting was dubious but rather than be diverted to chasing that sort of red herring we used our powers as trustees and raised the ante to $20.00 a volume. The librarian's letter of acceptance of the new conditions was overwhelming in its unenthusiasm. Nevertheless, Stanford went ahead with the program. Six months later the librarian announced that he was sending us *seventeen* books for destruction, and would we please forward the library a check for $340.00 so the program could continue at full speed? It was only a modest beginning, certainly, but at least it was a beginning. It began to look like we might get somewhere. And then—*the Harvard suit.*

Looking backward now, it seems rather surprising that as astute a businessman as Babcock did not foresee this argument. None of us here foresaw it—but we aren't Babcocks. It was a childishly simple argument, this invention of the Harvard Law School, but it was watertight.

A personal bequest cannot be made on condition that the beneficiary extirpate part of his person. You can't leave your nephew a million dollars on condition that he have his nose cut off. He gets the money without meeting the condition.

Harvard pointed out that a university is a legal person. Asking it to destroy part of its library is like asking it to destroy part of its person—ergo——. They have carried their case all the way to the Supreme Court and yesterday, as you know, they won the final round. We have been ordered to hand over the eighty million dollars to the four universities, *unconditionally.*

And that, gentlemen, seems to be that.

(There was a long pause.)

Mr. Falconer. Well, I guess we fold our tents. That's all, isn't it?

Mr. Adams. Oh, we have a couple of million in miscellaneous to dispose of.

Mr. Hungate. What shall we do with them?

Mr. Falconer. Isn't there some sort of gesture we could make with the money? Like setting up a foundation for the promotion of illiteracy?

(Laughter.)

Mr. Adams. Gentlemen, this isn't a funny occasion. Let's not make fools of ourselves. Something sensible now. This is a tragic occasion, and it ill befits us to behave otherwise.

Mr. Bell. Tragic is an understatement. Where in God's name will it end? Our libraries are doubling in size every sixteen years. There is no record of a human population continuously doubling in less than twenty-four-year intervals, and few have even approached that. Our own population is practically stationary now, but the multiplication of books continues unhindered. We won't even be able to store the index cards that tell where the books are. In 2040 A.D. the Yale library will need six thousand cataloguing librarians. If you continue the cal-

culations you find that a century later this one library will need 384,000 cataloguers. Another century and the figure is 23,000,000. Presumably, Harvard, Columbia, Princeton, Texas, and California and all the other big libraries will have grown in a similar way. Are we all to end up in the card-index room of a library? If everyone is cataloguing books, who on God's green earth is going to write them? I don't mean that would be a great tragedy, of course. But if all the world is covered with books and card indexes, where is man to live?

Mr. Calhoun. While we all have our hair down, I have four clippings from the morning paper which you may not have seen and which I'd like to read into the record. No, I won't read them, either; they all say the thing three times over, as newspapers always do. I'll just give you the gist of them.

First, here's a dispatch from Chicago which quotes the librarian as saying that during the next ten years the University of Chicago expects to acquire one million more volumes than it would otherwise have been able to, thanks to the thoughtful generosity of Mr. Babcock. The librarian goes on to say: "We expect to put our greatest efforts into strengthening the library of the Graduate Library School, buying upwards of 100,000 volumes in the field of library science."

Second, a report from Stanford. The librarian there says, and I quote: "As a result of the farseeing bequest of Mr. Babcock we shall be able immensely to strengthen and improve our accessioning and indexing system. At the present time we are struggling along on a mere $1.37—" it's gone up, I see—"1.37 a volume. The new bequest will permit us to institute the improved A.L.A. system, which will run the cost to around $5.00 a volume."

Mr. Hungate. It looks to me like Mr. Babcock overlooked something. He should have subsidized a series of research fellowships in librarianship, the fellows' efforts to be spent in devising new and improved systems of accessioning. In twenty years or so we could reasonably expect the "best" system to be so supercolossal and expensive that no library would be able to afford to acquire and accession another volume. Result—no more books acquired, no more problem.

(Laughter.)

Mr. Calhoun. Next, a report—you'll love this—from Columbia. Columbia has managed to purchase, for a mere $50,000, Professor Bumblebucher's entire collection of essays written by New York school children during the years 1930 to 1950 on the subject "What George Washington Means to Me." Accessioning this magnificent collection will cost an estimated million dollars. The dean of the Teachers College estimates that they should be able to squeeze at least thirty-five Ph.D.'s out of the material.

But perhaps the prize of all is a two-column article from Harvard on *their* plans. After a preamble in which the librarian tells what a tremendous problem theft is in a university library—Harvard, for instance, lost some 1,800 volumes last year, aggregating in value more than $15,000—he outlines their plans for stopping this disgraceful leakage. Books are to be made virtually inaccessible, of course. No stack permits to faculty members of whatever rank. All library workers to be bonded. No brief cases, notebooks, overcoats, pens, pencils, or paper to be permitted in the library, and no books to circulate. All books will be given a special coating of a radioactive material on the backbone, just under the cover. Exit from the library will be only through turnstiles guarded by Geiger-Mueller counters which will indicate the proximity of radioactive material by ringing a fire-alarm bell. The installation expense for all this Goldbergiana is estimated at $5,000,000, and the yearly maintenance at $150,000. It is expected to completely eliminate losses of books.

Mr. Bell. Oh, Christ.

(Silence.)

Mr. Bell. Since we seem to be through, I'd like to suggest that the board adjourn to my apartment where, in honor of the occasion, there have been gathered virtually unlimited supplies of Pilsener and Chateau Wente '47.

Mr. Adams. There being no objection—?

Mr. Hungate. How about the Red Cross? Let's give the two million to the Red Cross.

Mr. Adams. Is that agreeable with everyone? Very well, so be it.

Mr. Calhoun. Just a minute. I have an idea. You said, Mr. Adams, that you

thought that the minutes of this last meeting should be a sort of memorial, and so you read into them a history of the New Alexandrine Library Fund. How about making use of this memorial? Say, have these minutes hand-lettered on parchment, four copies, and send one to each of the libraries?

Mr. Bell. Gruesome, but I'm for it.

Mr. Hungate. At the same time, better appropriate a ten-thousand-dollar gift to each university for accessioning the document.

(Laughter.)

Mr. Adams. It is so ordered.

Mr. Falconer. Do we want the complete minutes done that way, including the reference to the wine and beer?

Mr. Bell. Damn it, yes. Including everything.

(Laughter.)

Mr. Calhoun. Hold on. I don't think we ought to let Chicago know about the termites. I move that all reference to the termites be expunged from the memorials. Those termites are our only remaining hope.

(No laughter.)

Mr. Adams. It is so ordered.

The meeting was adjourned at 1545.

The parchment manuscripts referred to on the plates have not been found, nor, in view of the peculiar end of the Worldly civilization, does it seem likely that they will ever be uncovered.

THE EAR OF DIONYSIUS

"All-seeing Eye"—but why the Eye,
  And not the Ear all-hearing?
Speed the thought, it made him spry—
  Dionysius a tyrant being.

Demanded he an Ear Immense
  For hearing avaricious.
In stone it grew through season tense,
  "The Ear of Dionysius."

It caught what eye could never gain,
  Nor missed the slightest stirring;
It picked the thoughts from Plato's brain—
  And packed him off demurring.

Since when the Ears wise men disprize:
  The fruits they yield are *rumors.*
Knowing ones prefer bright eyes;
  For eyes are moist with humors.

T. V. Smith

RELATIVE COOLING REQUIREMENTS FOR AMERICAN HOMES

By STEPHEN S. VISHER

PROFESSOR OF GEOGRAPHY, INDIANA UNIVERSITY

IN MORE than half of the United States outdoor temperatures are high enough during considerable periods to make house cooling distinctly desirable. The regional contrast in the duration of hot weather and its intensity is an aspect of climate that is becoming interesting to an increasing fraction of our people who hope to air-condition their homes.

The present article is a summary of some official data on high temperatures. It is a companion to the article on heating requirement contrasts in THE SCIENTIFIC MONTHLY for October 1945. It is less adequate than that article because data on high temperatures have been less thoroughly studied. This relative neglect of high temperatures is a natural consequence of the fact that house heating is indispensable in much of America, whereas house cooling is not. When houses are too warm, our health is not endangered; we merely feel uncomfortable and accomplish less work. Moreover, even crude shelters can be rather simply heated, whereas cooling requires expensive equipment and costly buildings.

Much evidence indicates that human efficiency declines at temperatures above 70° F. Indeed, some data assembled by Ellsworth Huntington and others suggest that for intellectual achievement the optimum temperature is below 65°.

Data on high temperatures of several sorts are available: (1) the highest temperatures ever officially recorded (the absolute maxima); (2) the average annual and monthly maximum temperatures; (3) the average daily maximum temperatures; (4) the normal, or mean, daily temperatures, computed by averaging the highest and lowest temperatures experienced; and (5) the average duration of high temperatures. Under this fifth category several aspects of high temperatures may be considered, such as the number of days when the maximum is above 90°, the number of days when the average of day-and-night temperatures is above 80°, the number of nights when the temperature does not fall below 70°. Finally, (6) of special interest from the standpoint of cooling requirements is the average number of "hot degree-day units." A day with an average day-and-night temperature of 71° has one such unit; a day with an average temperature of 75° has five such units; one of 85° has 15 such units. This "hot degree-day unit" is the converse of the "cold degree-day unit" discussed in the October 1945 article. Hot degree-day units have not been assembled by the Weather Bureau, which has done considerable work on the cold degree-day units, chiefly by, or under the direction of, J. B. Kincer. I have worked out average hot degree-day units from data on "Mean Daily Temperature Normals."

A map showing the highest temperatures officially recorded in the United States was given in "Temperature Contrasts in the United States," THE SCIENTIFIC MONTHLY for September 1942. There also were published maps of the average annual maximum temperatures and the average July temperatures. Hence, despite the relevancy of these maps to the present discussion, they are not reproduced here. The following descriptive summary requires so little

space, however, that it is justified. The whole country has had temperatures in excess of 100° except small areas in the mountains, along the northern Pacific Coast, in the Northeast, and in southern Florida. About three-quarters of the country has been hotter than 105°; nearly half of it has been hotter than 110°. In each of 20 states one or more localities have had maxima in excess of 115°, and five states have local records higher than 120°. (The national record is 134° in California, followed by 127° in Arizona and 124° in Nevada.) In the average summer the thermometers rise in about half of the country to 100°, and in about a fifth they rise to 105°. In the average year temperatures in excess of 110° are found chiefly in the arid Southwest (western Arizona, southern Nevada, and southeastern California). About four-fifths of the country has a July day-and-night average in excess of 70°, almost two-fifths has an average above 80°, and parts of Texas, southeastern California, and western Arizona have July averages of more than 85°.

Map 1 shows the number of days per normal year when the daily maximum temperature reaches or exceeds 90°. It reveals that nearly one-fifth of the country has fewer than ten such days, another fifth has more than 60, and a sizable area in the South and Southwest has more than 100—parts of it more than 140. (Yuma, Ariz., has 164 such days and 96 days of 100° or more.) This original map is based on the records of many regular Weather Bureau stations as presented in the official summaries to 1944, supplemented by deductions from "Average Daily Maximum Temperatures 1916–1935" (official, mimeographed, 1944).

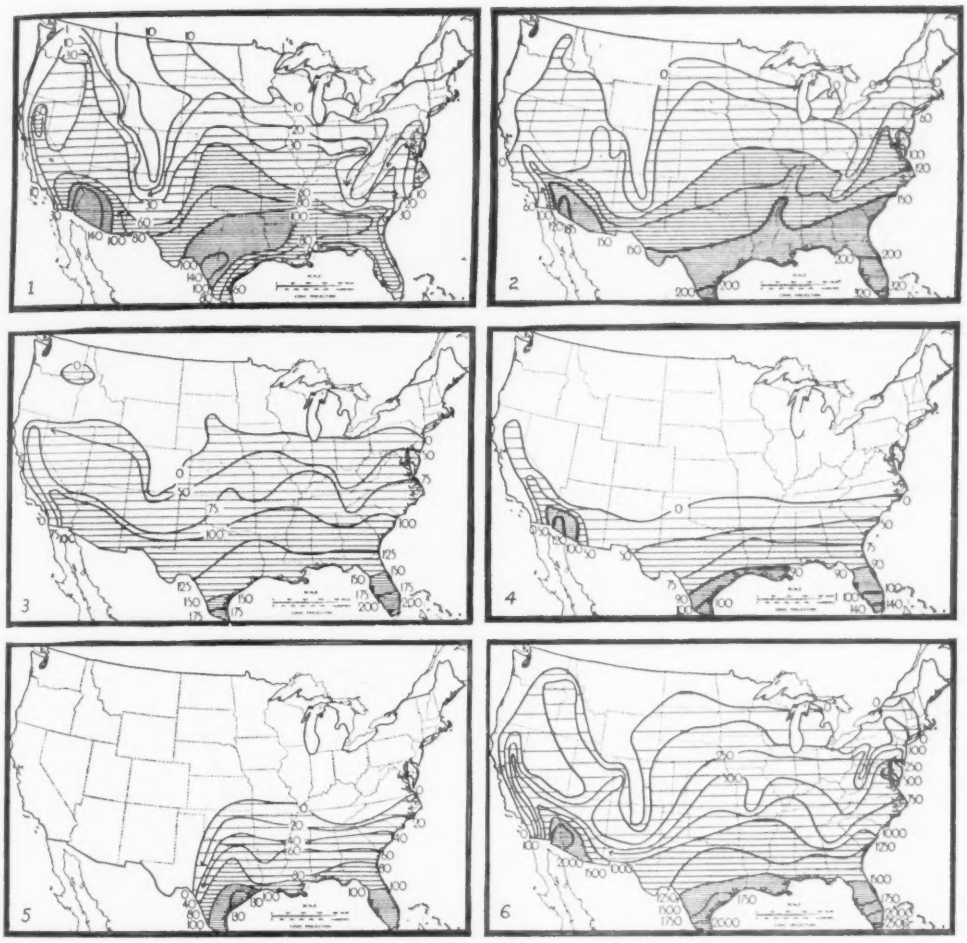
Map 2 indicates the average number of days per year having daily normals (average of day and night) above 70°. The middle of the country north and south has about 100 such days, whereas the northern border and most of the Pacific Coast have none. By contrast, near the Gulf of Mexico nearly 200 days have normals above 70°; southern Florida has more than 300 such days. This original map is based on the data given in the official "Normal Daily Mean Temperatures" (Supplement 25, Monthly Weather Review).

Map 3 shows that very hot weather (day and night averaging 75° or higher) is lacking in approximately a third of the country, but that it is normal for more than four months along the Gulf Coast. (This map is new; same source as Map 2.)

Daily normals above 80° (Map 4) are almost restricted to the southern states and the Great Valley of California. Southern Texas and most of Florida have more than 90 days averaging above 80°. (This map is new; same source as Map 2.)

When the nights are relatively cool for several hours, permitting restful sleep, more daytime heat can be successfully withstood than when the nights are hot. Map 5 shows the number of nights per average year when the temperature does not fall below 70°. This map supplements the foregoing ones by indicating large contrasts in the need for air conditioning. It reveals that along the Gulf Coast there are about 80 such enervating nights per year, while in southern Florida there are more than 100 (111), and in part of southeastern Texas as many as 135 such nights. Map 5, new, is based on data deduced from the official "Average Daily Minimum Temperatures 1916–1935."

Map 6 presents the average annual number of hot degree-day units (total degrees above 70° times the number of days, derived from the daily normals). It reveals that the northern and western



MAPS 1–6. HIGH TEMPERATURES IN THE UNITED STATES

1: DAILY MAXIMUM TEMPERATURES OF 90° F. OR HIGHER (AVERAGE NUMBER OF DAYS PER YEAR). 2: AVERAGE DAILY TEMPERATURES (NORMALS) ABOVE 70° (NUMBER OF DAYS PER YEAR). 3: AVERAGE DAILY TEMPERATURES (NORMALS) ABOVE 75° (NUMBER OF DAYS PER YEAR). 4: AVERAGE DAILY TEMPERATURES (NORMALS) ABOVE 80° (NUMBER OF DAYS PER YEAR). 5: HOT NIGHTS; AVERAGE NUMBER OF NIGHTS PER YEAR WHEN THE TEMPERATURE REMAINS ABOVE 70°. 6: HOT DEGREE-DAY UNITS, NUMBER PER NORMAL YEAR (SUM OF TEMPERATURES ABOVE 70°).

borders of the country and the high western mountain region normally lack hot degree-day units. By contrast much of the southern part of the country has more than 1,000 such units and the southern parts of Florida and Texas have more than 2,000 units.

Map 6 indicates a sharp southward increase in the need for cooling. For example, New York City has about three times as many hot units as New Haven; Philadelphia, nearly twice as many as New York; Washington, a fourth more than Philadelphia; Atlanta, more than twice as many as Washington. Similarly, Cincinnati has nearly four times as many hot units as has Detroit; St. Louis, about twice as many as Cincin-

nati; and Memphis, almost twice as many as St. Louis. The cities on the Pacific Coast have no hot units except Los Angeles (the main part of which, including the Weather Bureau station, is some 20 miles inland), which has 45, the same number as Erie, Pa.

A seventh map, not published here, portrays the average number of hot degree-day units during the nine cooler months, September to May, inclusive. It reveals that more than half of the country does not have any daily normals above 70° during most of the year. Conversely, the southern states have more such hot days in spring and fall than most of the North has in summer. The southern parts of Texas and Louisiana and most of Florida have more than 500 hot degree units in spring and fall (Key West has 1,463); southwestern Arizona and the nearby part of California also have more than 500 units, Yuma having 730.

These maps, based on official data, reveal sharp regional contrasts in the intensity and duration of high temperatures and hence the need for artificial house cooling, if maximum comfort and intellectual activity are to be attained. The South and the arid Southwest are conspicuously hot except on the coast. The dry heat of the arid region is notably less enervating than the "sticky heat" of the humid South. The humidity of the South not only renders high temperatures more trying but it makes air conditioning distinctly more difficult. When moist hot air is cooled, condensation is induced. Insofar as the relatively mild winters in the South encourage the construction of poorly insulated buildings, artificial cooling in hot weather is rendered less efficient.

A FULL UNIVERSE

EDWARD ROSEN

To TRACE the history of a fundamental idea through its encounters with rivals and opposites, to analyze its modifications and progeny, its allies and its enemies, its spread and decline, is a fascinating enterprise requiring philosophical acumen and wide learning. A splendid example of this newer type of historical investigation was provided by Arthur O. Lovejoy's penetrating study of a decade ago, *The Great Chain of Being*, which focused its attention on Plato's fecund doctrine of the full universe—christened "the principle of plenitude" by Lovejoy. The plenitudinarians, or plenists, saw in the realm of nature a vast ladder reaching down to the lowliest forms of life and rising rung by rung through progressively diminishing degrees of imperfection to that crowning glory of creation—mankind. Upon this ladder of natural beings otherworldly minds superimposed a hierarchy of disembodied spirits, ranging through various gradations of Intelligence to the Highest Good, for those of a metaphysical or mystical bent, and for those of a theological persuasion, through ascending orders of Blessedness to the Highest God. This organization of the sensible or supersensible world was mirrored in the structure of society, which comprised men and women of every level, from the humblest laborer toiling at a menial task to the most exalted dignitary. There were no gaps, no chasms; every potential type of existence was actualized. Like a nation with a housing shortage, the universe was full.

The principle of plenitude long dominated astronomical thinking, too, in a way that somehow escaped Lovejoy's vigilant eye. It may be instructive to trace the fortunes of this ascendancy, from its rise in the Greco-Roman world of antiquity to its collapse in the Renaissance, when the age of unaided naked-eye observation was drawing to an unlamented close.

We may begin our little history with Claudius Ptolemy, in whom man's persistent effort to discover the pattern of the cosmos attained, by common consent, its first great culmination. The Platonic principle of plenitude united with the Aristotelian concept of continuity to produce a vision in Ptolemy's mind of a tightly-knit universe with no empty space. In his major work, the *Syntaxis* (long known, by reason of Arabic adulation, as the *Almagest*), he attempted to ascertain the maximum and minimum distances of the sun and moon from the earth by the method of parallax, which is still the principal avenue of attack on this problem. Although his values for the sun were far too low, in the case of the moon his numerical results were astonishingly good. But however accurate or inaccurate his conclusions may have been with regard to the sun and moon, the method itself was inapplicable to the planets since, as he sadly admitted, "none of them shows a perceptible parallax, the only phenomenon by which the distances are determined."

What sort of picture of the universe, then, confronted the diligent reader of the *Syntaxis*? He knew (or thought he knew) how far from the earth the sun and moon were; but, as for the planets, only their relative distances were disclosed, and it was acknowledged besides that no observational means were available to compute the exact distances. Thus the powerful human craving for an answer to the question "How far?" was

left unsatisfied. Even Ptolemy must have felt the tug of this frustration, for in a subsequent work he adopted a non-observational approach.

In the *Hypotheses of the Planets* he rejects Plato's arrangement of Mercury and Venus above the sun with the following application of the principle of plenitude to cosmic space:

> Mercury and Venus must be located not above the sun, but between the sun and the moon, lest this space, which is so vast in accordance with appearance and also with our conclusions about the distances, remain empty, as though nature had forgotten and neglected it, and hence made no use of it. Yet it is capable of encompassing the distances of both the above-mentioned planets, which are nearer than the others to the earth, so that this space is exactly filled by the two planets alone.

Ptolemy advanced this argument only to support his contention about the relative distances of the inferior planets, and there he let the matter rest. But his words carried an implicit suggestion which was seized upon by later generations. Had not the prince of astronomers said that Mercury and Venus *exactly* fill the interval between the sun and moon? Did this not imply that Mercury's least distance from the earth—its perigee—must be equivalent to the moon's greatest distance from the earth—its apogee? By the same token, must not the sun's perigee equal Venus' apogee? But the lunar apogee and solar perigee were perfectly definite numerical quantities, for Ptolemy had measured them in terms of radii of the earth. Well, then, the perigee distance of Mercury and the apogee distance of Venus were known, too. The riddle of the planetary distances was beginning to yield before the onslaught of the plenists.

They now opened the second phase of their offensive. If there is indeed no empty or unused space in the universe, then of course Mercury's apogee must be identical with Venus' perigee. To be sure. But how could one fix the line of demarcation? This difficulty was overcome by utilizing the relative dimensions of the circles whose combined action, according to the *Syntaxis*, produced the orbit of each body. The ratios which Ptolemy had computed for these circles were an integral part of his planetary theory. But that theory had itself been modestly designed to represent, in the closest possible agreement with observational data, the angular motion of the planets without regard to their actual distances. Thus, the end product of a series of purely geometrical calculations was joined with entirely independent observational results, under the auspices of the principle of plenitude, to furnish a supposedly accurate determination of the maximum and minimum distances of Mercury and Venus.

The unfolding of this procedure can be studied in the pages of Proclus, who succeeded to the leadership of the Neoplatonic Academy in the fifth century A.D. Proclus wrote an elementary introduction to Ptolemy entitled *Hypotyposis*, or *Outline*. At the end of this book he summarized his results in a series of conclusions, among which we find:

> The seventh concerned the disposition of the planets, which has been discussed in an earlier section. Now some people, relying on the perigees and apogees, conclude that the lunar apogee nearly coincides with the perigee of Mercury, as does the apogee of Mercury with the perigee of Venus, and the apogee of Venus with the solar perigee, so that the order of these bodies with respect to one another is revealed by these relationships.

After citing Ptolemy's numerical determinations for the sun and moon, the neoplatonic philosopher-mathematician reports that the same unnamed persons, "assuming that there is no empty space in the arrangement of the universe . . . undertook an examination of the apogees and perigees of Mercury and Venus to see whether these could fill out the aforesaid numbers." Through the use of Ptolemy's ratios for the constituent cir-

cles in the theory of these planets, the line of demarcation between Mercury and Venus was established. Proclus closes a similar passage in his *Commentary on Plato's Timaeus* with these words:

> Clearly, the spheres of Mercury and Venus must be placed between the moon and the sun. For the moon's greatest distance coincides with the least distance of Mercury; Mercury's greatest distance with the least distance of Venus; and the greatest distance of the latter with the sun's least distance, almost exactly. For there must be no empty space."

The prestige of the plenists was heightened in the following century by the (mistaken) assertion of Simplicius in his *Commentary on Aristotle's De Caelo* that the details had been worked out by Ptolemy in the *Syntaxis*. Thus, according to the most influential commentator on the greatest philosopher, the foremost astronomer in his major work had obtained observational data in agreement with deductions from an a priori principle. What more could anyone ask?

Beneath this analysis lies a conception of the physical universe which may be likened to a succession of grapefruit rinds or layers of onion skin. The inner surface of the rind represents the perigee distance of the planet, and the outer surface corresponds to the apogee. As each planet moves on its majestic course, it will always be found somewhere within its heavenly rind. The outer surface of each rind fits snugly within the inner surface of its next larger neighbor, and the entire universe consists of a small number of such rinds, or spherical shells, from the innermost center to the outermost surface, the flaming ramparts of the world.

When intellectual hegemony passed from the declining Greco-Roman civilization to Islam, the Muslim scientists in the main founded their cosmology on Ptolemy's system. Accepting the principle of plenitude, they extended its application by parity of reasoning from Mercury and Venus to the remaining planets and the fixed stars. From their labors there emerged a cosmos whose dimensions were known throughout. This tidy and comforting notion was diffused from the Arab centers of learning to the West when interest in scientific questions revived. For centuries the principle of plenitude ruled supreme without any serious challenge.

THE long reign of the Ptolemaic cosmology faced its first major upheaval when Copernicus subverted the established order of the planets. But his transfer of the sun to the central position and his identification of the earth as a planet wandering in the middle reaches of cosmic space entailed a huge outward thrust of the uppermost spherical shell, the region of the fixed stars. For as the earth traverses its annual orbit about the sun, it should produce an alteration in the apparent position of any fixed star. If this is noted of a clear night and then again six months later when our mobile observatory, the earth, has swung round to a diametrically opposite point on its yearly circuit, the star should appear to have shifted somewhat in the meantime. For, although the star itself may have remained constant, the line of sight now approaches it from an altogether different direction. And yet no such annual parallactic shift could be observed, for it is too minute to be discerned with the unaided eye. To account for its absence, Copernicus was constrained to postulate an enormous remoteness for the fixed stars. Between them and Saturn, the highest of the planets, yawned a vast emptiness. What could possibly serve as filling for this immense gap? The rumbling produced by this insistent question caused the principle of plenitude to totter on its shaky throne.

Tycho Brahe, the last great naked-eye observer before the invention of the tele-

scope, deeply admired the Copernican system and recognized the genuine advance which it signified for astronomical thought. In particular he saw how radically planetary theory was simplified by having the planets revolve around the sun; their stations and retrogressions were correctly explained by the novel Copernican doctrine, and also the variation in their distances from the earth and in their apparent magnitude. But Brahe balked at accepting a moving earth—the very idea was repugnant to his metaphysical and religious preconceptions. And he was so thoroughly obsessed by the principle of plenitude that he regarded the vast gap between Saturn and the stars as a grave defect in Copernicus' world view. Hence, when he set about devising his own blueprint of the cosmos, he combined a stationary earth with heliocentric orbits for the planets.

Following the lead of Copernicus' first disciple, he somehow imagined that his own superb collection of observations justified the (perfectly sound) conclusion that Mars at opposition is nearer to the earth than is the sun; hence their orbits must intersect. And since they intersected, the orbits could not be material shells. Thus it was that Tycho Brahe, the confirmed plenitudinarian, delivered the knockout blow to the trembling principle. For, if the spherical shells were not real, there could no longer be any debate whether they were neatly joined or separated by interstices. They simply ceased to exist, save in the imagination for purposes of instruction. Tycho's proclamation of their death sentence is of such great importance to the history of ideas that it deserves quotation:

> The celestial mechanism is not a hard and impenetrable body filled with various real spheres, as has been generally believed heretofore, but it is a highly fluid and utterly simple substance. The planets revolve freely without being assisted or carried about by any real spheres. . . . In this arrangement of the heavenly bodies no absurdity follows from the fact that Mars at opposition comes nearer to the earth than does the sun. For this view admits no actual and incongruous interpenetration of the spheres (since they do not in fact exist in the heavens, but are set forth merely for the purpose of instruction and comprehension of the subject). Nor can the planetary bodies ever collide, or in any way disturb the harmonious motion which each of them pursues, however the imaginary spheres of Mercury, Venus and Mars may mingle with the sun's and cross through it.

The nonexistence of material spheres was confirmed by his discovery that the fiery comets rush freely about in cosmic space, beyond the moon amid the planetary orbits.

Tycho took a boundless pride in his unsound compromise between the stationary earth of Ptolemaic and Biblical tradition and the heliocentric planets of Copernicus. When Nicholas Reimers, surnamed Ursus (the bear), who was Imperial Mathematician to Rudolph II, Holy Roman Emperor, claimed priority in the invention of the Tychonic system, Brahe's wrath hounded the unhappy wretch to his grave and beyond. But Reimers made no provision for a closer approach of Mars to the earth than the sun's least distance. The tremendous implications of this fact, as first enunciated by Brahe, have already been set forth. And yet a reputable historian of astronomy declares, after due consideration, that this difference between the cosmologies of Brahe and Reimers is a negligible trifle!

If Copernicus struck the principle of plenitude in the solar plexus and Brahe delivered the knockout blow, it was Kepler who counted ten over the prostrate form. For when he discovered that the paths of the planets are ellipses and not circles or combinations of circles, he forever dissociated the heavenly bodies from unseen carrying spheres or spherical shells. The last hopes of the (reasonable) traditionalists perished when

the motion of the heavenly bodies was shown to be a product of the mutual attraction of their material masses and not of their ceaseless yearning for an unattainable perfection nor of the unperspiring exertions of Intelligences or Souls or Angels.

Yet the doctrine of the full universe, driven from the heavens, clung tenaciously to life on the earth. If a column of mercury rose in a barometer, nature was evidently filling an empty space, because it abhorred a vacuum. But somehow this distaste relaxed a little just before a storm, when the pressure of the atmosphere fell, and the same slackening occurred on the roofs of tall buildings and at the tops of mountains, where the air was less dense.

After the triumphant synthesis of terrestrial and celestial mechanics in Newton, the idea of fullness, divorced from the principle of continuity or contiguity, reappeared in modern astronomy in a new dress. The planets were known to be strung out at varying intervals in space, like beads on a celestial necklace. But when they were arranged in the order of their distance from the sun, was there not perhaps some underlying simple numerical relationship which could bind the several discrete bodies into a single, harmonious, organic whole? The most plausible suggestion of this sort—Titius,' or Bode's, law—called attention to the vast emptiness between Mars and Jupiter and led to the belief that a missing member of the series was still in hiding somewhere. When the accidental telescopic discovery of Uranus for the first time extended the chain of planets beyond those known to the ancients, it seemed to confirm Bode's law and provoked a systematic search to close the gap between Mars and Jupiter. At the opening of the nineteenth century there was found the first of the asteroids—that multitude of tiny bodies representing either the fragments of a disintegrated planet or the component parts of a planet that somehow failed to coalesce. Like Mendeleyev's Periodic Table of Chemical Elements, the arithmetical relationship pointed the way to the discovery of the unknown. In this quantified form, then, the principle of plenitude is applied to the solar system, and from time to time fresh attempts are made to remedy its imperfections and to learn whether it does indeed answer to some as yet dimly understood distribution of cosmic matter.

THE MARIANAS, CAROLINE, AND MARSHALL ISLANDS[1]

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MANY Americans have wondered what Uncle Sam will do with the Mandated Islands taken from Japan during World War II. What can be done with the hundreds of Micronesian islands that are now under the military surveillance of the United States? The Marianas, Caroline, and Marshall Islands extend over 3,000 miles of the Pacific, yet the total land surface of 846 square miles is less than that of the state of Rhode Island. The 206 square miles of Guam, a possession of the United States since 1898, is in addition (see accompanying map).

The Marshalls are flat, sandy, coral islands, while many of the larger Caroline and Marianas islands are a combination of volcanic cores and coral reefs. The latter are comparatively rough but have small plateaus and coastal flats which are reasonably free from lava and coral obstructions. Most of the Mandates lie between 5° and 15° north latitude and accordingly have a tropical climate, with relatively heavy rainfall—particularly in the southern portions of the Marshalls and Carolines. The Marianas are characterized by a "dry season" from January to April, the severity varying considerably from year to year.

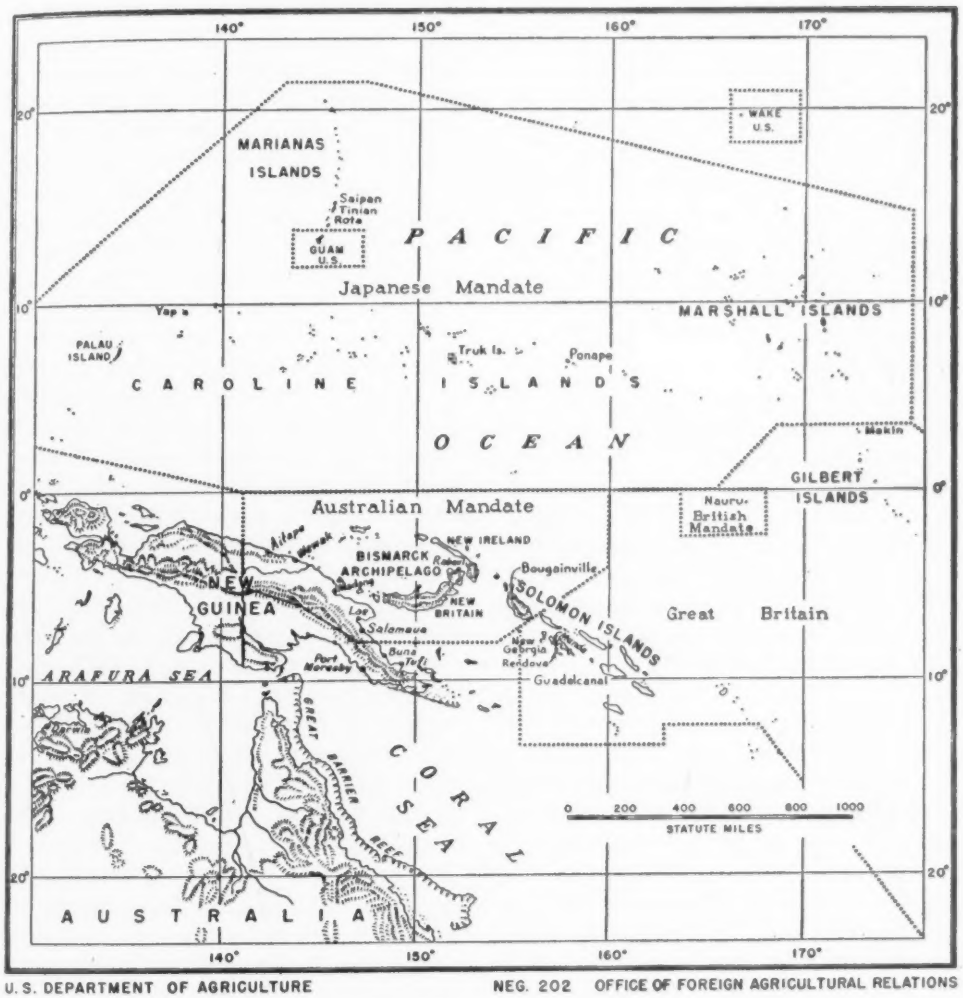
In 1937 the total civilian population of the Mandates was 112,267, of which 61,323 were Japanese colonists, 50,809 were natives, and 135 were of other origins. In addition, Guam possessed a population of 22,290 (1940), 90.5 percent of which were native Chamarros. The recent aboriginality of the natives, particularly the Carolinians and the Marshallese, and their crude living habits are of interest to most visitors to these islands. Many of the natives prefer to live from the roots and fruits of the land rather than exert sufficient effort to produce domestic foods. The culture of the Chamarros in the Marianas has been advanced considerably as a result of Catholic missionary influences introduced early in the seventeenth century by the Spanish. The resulting ideals and customs orient these people toward the West rather than the East.

The history of these islands has been varied and fascinating. The Spanish discovered the Marianas in the sixteenth century and by early in the seventeenth had established a limited administrative hold on all three groups. Until 1898 Spanish rule of the Marianas and the Carolines had been undisturbed. Guam was ceded to the United States during the course of the Spanish-American War (1898), and in the following year the remaining islands of the two groups were sold to Germany. Germany had exercised a protectorate over the Marshalls for a few years previously, and her claims were uncontested until 1914, when the Japanese began unofficially to organize the South Seas Government and to colonize the sparsely populated islands. In 1922 their claim was supported by the League of Nations mandate which provided authority over all three groups, with the exception of Guam in the Marianas.

There is a question now as to what the

[1] A fully documented article entitled "Resource Development in the Pacific Mandated Islands," by the same author, appeared in the *Journal of Land and Public Utility Economics*, August 1946.

[2] In addition to the references listed, this article is based on observations made by the author while on duty as Agricultural Officer, Naval Military Government, in the Pacific Ocean area. The author is solely responsible for all interpretations and conclusions made.



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THE MARIANAS, CAROLINE, AND MARSHALL ISLANDS

future holds for these distant microislets. Social scientists are proclaiming the need for reformation, the development of economies, the advancement of civilization. Our discussion poses some of the questions and problems which will be involved in any attempts to develop the resources of the Mandates. In the light of past development and the natural resources available, it should be possible to visualize some elements of the economic future for these native peoples, under the general assumption that the United States will continue to control the Mandates. However, questions of political policy will be avoided; likewise, the method of government and the bureaucratic problems involved are not a part of this discussion.

Natural Resources

The distant and scattered location of the Mandated Islands imposes a negative influence on the possibility for developing the relatively meager natural resources. The small, flat, coral islands of the Marshall group are relatively infertile, and the range of possible commercial productivity is very narrow. The coas-

tal flats and plateaus of the larger volcanic islands in the Carolines and Marianas offer some greater possibilities. The soils, consisting mainly of volcanic mud, coral residue, and varied organic content, are more fertile. In the best locations they are quite readily worked and provide a fair medium for vegetable and sugar-cane production. Plant growth is usually rapid, and some crops may be grown the year around, depending mainly on rainfall, insects, and disease.

The Spanish made little effort to develop the available land and marine resources. Shells and small amounts of copra were bartered from the natives. A naval base was established on Guam. Otherwise, the Spanish Pacific possessions were merely missionary outposts.

The Germans were more aggressive in some respects. They exerted considerable effort to develop both copra and the phosphate deposits. The United States made no attempt to develop or to secure trade with any of these islands, even though its Guamanian possession might have been a key trading post for the entire area. However, the Japanese were operating plantations and trading in copra in both United States and German territory prior to their first colonization in 1914. In that year they seized the German-developed phosphate mine on Angaur, West Carolines, and the railroads and other facilities in the Marianas. By 1922, when the mandate was effective, the South Seas Government was well under way toward developing the most favorable resources throughout the entire area.

The Japanese recognized that the islands were lacking in knowledge, essential skills, and cheap labor. Accordingly, they transferred these factors of production from Japan, Okinawa, and Korea by colonization. Moreover, the South Seas Government provided substantial subsidies to commercial enterprises in behalf of preferred types of production. Several agricultural experiment stations were established primarily for improving and developing sugar cane and cotton. Numerous fruits, vegetables, and shrubs were being acclimated and tested.

Land Utilization. The Japanese reported approximately 135,000 acres of cropland in the Mandates for 1937. Three qualifications are necessary, however. First, almost half of this acreage consisted of coconut and breadfruit lands, most of which is more or less unattended natural flora. Second, at least 60 percent of the sugar-cane lands in the Marianas is too steep to be tilled by means other than bulls and hand labor. These the Japanese used almost exclusively. Third, these estimates by the South Seas Government represent conditions existing before the war. Military installations since have been made on a substantial proportion of the land that was formerly the most suitable for agricultural uses. Derangement by grading, coral overlays, and other factors have greatly impaired these locations insofar as farming is concerned, even if all military uses were discontinued. With these qualifications in mind, the character of land use under the Japanese and the potential utilization pattern may be more clearly visualized.

Saipan, Tinian, and Rota Islands in the Marianas possess almost 82 percent of the 45,200 acres of *cultivated* cropland in the Mandates (excluding Guam), as reported for 1937. Sugar cane accounted for 76 percent of all cultivated land in the Marianas, and 62 percent of that for the entire Mandates. Fruits, vegetables, and minor fiber crops constituted the remainder. In addition, it was estimated that there existed 53,500 acres of undeveloped *arable* land, 85 percent of which is supposed to be in the Marianas. It is certain, however, that most of this acreage must be quite rough and usable only by hand processes. Lands which have not been developed consist of steep, rough, infertile ridge

tops that are subject to severe drought during eight months of the year.

In the light of these circumstances and after appropriate deductions for lands totally or partially destroyed by military activities, it is probable that not more than 10 percent of the lands farmed by the Japanese could be so used by methods similar to the commercial practices employed in the United States. Most of this acreage is in the Marianas.

In order to complete the picture for the three groups of islands, it may be worth while to note that the Guam Agricultural Experiment Station reported a total of 17,000 acres under "cultivation" in 1939. Actually, only 4,000 could be correctly described as cultivated, this acreage being devoted to corn, rice, sweet potatoes, tapioca, taro, and other fruits and vegetables. The remainder is coconut plantations. Breadfruit and coconut lands are often suitable for other uses if cleared. But the natives are strongly opposed to destroying any natural sources of food. They apparently never will forgive the Japanese for replacing the coconut with sugar cane.

The native Chamarros, Marshallese, and Kanakas, or Carolinians, do very little land cultivation if left to their own way of life. They prefer to depend heavily on the spontaneous native products which require a minimum of care and attention. Bananas, breadfruit, coconut, taro, sweet potatoes, yams, and other foods of perennial growing habits are a major source of their diet. Small patches of corn, squash, eggplant, and beans may sometimes be planted, but after planting they are often neglected. Even on Guam, where considerable effort has been exerted since 1909 in improving Chamarro farming, most of the native farms can scarcely be distinguished from the bush. However, the U. S. Military Government farm program on Saipan was reasonably effective under an association type of organization. Small 2-acre units were constantly supervised by native leaders, and various types of encouragement were provided.

Minerals. Japan valued the phosphate deposits of the Mandates very highly. Supplies of this fertilizer are needed in large quantities for home-island agriculture. Both rock and guano phosphates were mined in several locations, the principal developments being on Anguar, Fais, and Peleliu islands in the West Carolines, and on Rota and Saipan in the Marianas. More than 300,000 tons were taken from these locations in 1939.

The remaining deposits are estimated to be three to four million tons of high-grade rock and probably twice this amount of low-grade rock. The best rock is reported to vary from three to six feet in thickness.

In addition to phosphate, small deposits of aluminum, manganese, coal, lignite, and others are reported for various locations. Some have been worked on an exploratory basis; but it is unlikely that they have commercial development possibilities, except under special circumstances such as characterized the Japanese war efforts.

Fisheries. The entire Mandated area is well supplied with numerous types of fish. Japanese fishery operations in this area were centered in Palau, Truk, and Ponape in the Carolines, and at Saipan. Although the total catch obtained from these locations represented less than 1.5 percent of the Japanese Empire catch prior to the war, there is reason to believe that fishing may be an important aspect of the future economic development of the area.

In addition to commercial fishing, the natives normally depend on lagoon and reef fishing for numerous types of sea food. Fish are an important item of native diet since livestock are not produced in sufficient amounts for providing adequate meat supplies.

Shells, shark fins, sponges, and pearls form the basis for an important part of

the island handicraft production, and expansion of this industry may be feasible. The Japanese sponsored pearl and shell enterprises, especially in the Carolines, where these resources are most plentiful.

Sea-food processing consisted of drying, principally; two small canneries were operated in the southern portion of the area. All these facilities, including fishing boats, were destroyed during the war. Military Government units rehabilitated and added certain facilities in behalf of local food supplies for interned civilian populations.

Livestock. Japanese and native livestock production was limited to work stock and subsistence swine, poultry, cattle, and goats, with the exception of a few dairy cattle. Two small dairies on Saipan are known to have produced milk for sale in the towns of Garapan and Chalan Kanoa. But, according to Japanese records, less than 20,000 gallons of milk were produced annually in all three island groups. Most cattle were kept for draft and occasional slaughtering. Usually the consumption of beef and pork was limited to festive occasions, which are the very spice of native life.

Shortly before the war the Japanese initiated some hog projects in the northern Marianas. The aim was to provision troops stationed in the central Pacific. The hogs were fed from the native supply of copra available in these undeveloped small islands.

During the course of hostilities on the larger islands all livestock were released to roam at will. Military Government units have corralled sufficient numbers of cattle, poultry, and hogs to provide a source of breeding stock for the natives.

Industry. Sugar mills were the principal industries established by the South Seas Government interests. Three mills on Saipan and Tinian were capable of processing 34,000 tons of cane daily. Other mills were located on Rota; all were in the Marianas. Sugar, molasses, alcohol, and alcoholic beverages were processed in one or more locations.

Sustaining and subsistence industries were operated in several locations. For example, narrow-gauge railways, small cement plants, salt evaporators, charcoal ovens, handicraft shops, copra mills, and limited food-processing plants were operated at several points. Some exports from them were possible, but their primary function was to supply local needs.

Insofar as food production was concerned, copra and tapioca (cassava) starch took important positions, subordinate to sugar and fish only. The Marshalls and Carolines are reported to have processed more than 17,000 tons of copra for export in 1937. It is likely that this amount could be increased substantially by providing essential labor in the proper locations. Saipan, Palau, and Ponape produced an estimated total of 5,500 tons of tapioca starch in the same year. The cassava plant is a prolific producer of the starch-bearing tubers and may be grown on the rough coral lands that are not suited for certain other uses. Moreover, the production period is comparatively short. In terms of food supplies this crop may offer real possibilities where labor and processing facilities can be made available.

Small industries of this kind were, and probably will continue to be, important to the Japanese. Numerous subsidies were granted in behalf of every possible addition to food and raw material supplies. The *natives* have played little part in the enterprises of the South Seas Government, except as lands were leased from them. The more ambitious and talented were employed in various capacities.

Potential Development

War left the Japanese Mandated Islands in a state of destruction. Towns, mills, processing plants, and all other facilities were reduced to ruin. Sugar

cane, pineapples, bananas, papaya, coconut, and numerous other native food sources may readily be rejuvenated and expanded. Sufficient hogs, cattle, goats, and poultry have been corralled by Military Government units to form the basis for improved subsistence meat supplies.

In several locations Military Government agricultural programs have provided substantial facilities for rehabilitating subsistence agriculture. The United States Commercial Company has installed extensive facilities in several locations; in addition to the dairy and swine farms established on Guam, the U. S. Commercial Company has provided sizable vegetable and fruit production projects on Saipan, Tinian, Guam, Truk, and Peleliu. As the Japanese and Koreans were repatriated to their native lands, the U.S.C.C. also took over certain portions of Military Government farm projects in behalf of the subsistence of remaining natives. Some fishing and the handicraft industry projects previously established probably will continue to be basic functions of the meager native "economies."

In terms of commercial development of any type, however, the repatriation of the Japanese colonists removed essential labor supplies. Native labor almost certainly will remain more or less fully employed by the island military establishments and for island maintenance and service needs in most locations. This means that additional labor must be obtained from somewhere for any substantial resource development work.

United States Interests. It is not readily conceivable that the United States will have any strong interest in the limited resources of the Marshall, Caroline, and Marianas islands. Long distances, relatively high cost of production, and the interests of established producing areas are only three of the factors which are likely to limit United States interest in these islands to the military sphere. The administration of Guam as a naval base since 1898, with little attention to resource development, is sufficient precedent.

Of course there is a substantial responsibility for native welfare, which United States Military Government has made great efforts to improve. Hospitals, health services, employment at relatively high wages, expanded supplies of consumer goods, and numerous service functions have been provided. Schools, churches, and housing projects have already raised the native levels of living far above their means to maintain, unless continuous subsidies are provided.

The Agricultural Experiment Station which was maintained on Guam for 23 years was discontinued in 1932 because of lack of appropriations. Although considerable knowledge on island agriculture had been accumulated, this action was indicative of a lack of interest in natural resource development. The most important accomplishment, perhaps, with respect to creating trade with the Island of Guam, was the improvement in the quality of copra offered to the export market. However, island government, rather than agricultural interests per se apparently were responsible for this.

Copra probably is the only resource of these islands which United States trade interests may consider seriously. Since coconut production requires little attention (where the scale insect is not prevalent), copra may be produced with a small investment. Labor and drying facilities are all that are required. And it is possible that sufficient native labor could be made available for operating a worth-while copra trade, in a few locations at least.

Saipan, Tinian, and Rota, however, are practically void of coconut, and these three islands comprise the only substantial farm land acreages available for development. Hence, for the immediate future copra offers no opportunities in these locations. The chances are that the

natives may exert considerable pressure to have suitable farm lands assigned, at least to former landholders under the Japanese, for subsistence production. This may involve a redistribution of Saipan's present population of 4,200 Chamarros to Tinian and Rota. The latter islands were almost completely populated by Japanese colonists who have been repatriated to their native lands.

If United States trade in copra should be developed, there is reason to believe that small amounts of handicraft may become a supplementary item of trade. Limited quantities of raw materials and comparatively low quality workmanship, however, may limit handicraft to local trade with tourists and military personnel.

There is a strong possibility that commercial companies may be interested in developing the phosphate resources for supplying demands in the Philippines, Japan, or in China. The distances to the States put domestic markets out of range. But acute demands nearer by would undoubtedly take all that could be produced. Other minerals probably are not of sufficient importance to attract development by domestic interests.

So far, no provisions have been made for permitting access to resources of the islands for private development. Presumably, this would be possible after the final peace treaty has been consummated and within the bounds of military security. Operations of the United States Commercial Company gained access to land resources to aid the military efforts. Now that this program is in the process of liquidation, there will be no organized development of resources in the Japanese Mandates unless some new commercial or public effort is advanced.

There seems to be no good reason why the United States should subsidize any aspect of development other than that essential to security and reasonable levels of native welfare. Local employment of natives for military, island government, and service trade work, as already pointed out, is likely to absorb all native employables for some time to come. Private handicraft, farming, and other small native enterprises will undoubtedly give employment to some of those who prefer such work and to some who may not be able to adapt themselves otherwise. If copra and other supplementary trade is developed by private interests there is little doubt about the full employment of all natives. The development of a socioeconomic situation based on local trade and employment is more likely to insure a higher and more stable level of welfare than would be obtained by artificial economic relationships based on government subsidies, which are almost certain to be temporary.

Other Interests. It is impossible to appraise the possibility that various foreign interests may develop the limited resources of the Japanese Mandates because of the many unknown factors and relationships that may be involved. The extent that military security will allow resource development and the provisions by which resources might be made available are only two of the factors involved. These are outside the limits of this discussion.

However, the demands of nearby starving Asia for the smallest addition to food and raw materials supplies give impetus to the question of making available unused resources accessible for utilization. It is impossible to ignore the existence of Pacific island resources when the world is being searched for resources which will add to food supplies for needy areas. This applies not only to land, but to phosphate fertilizer, which is so generally needed by the areas which the United Nations are attempting to rehabilitate.

Problems of Development

The development of resources in the Marshalls, Carolines, and the Marianas

will involve numerous problems, irrespective of the character of the developing interest. The most apparent difficulty is the general lack of labor, unless unforeseen supplies come into the picture. The Chamarro population of less than 4,500 remaining on Saipan, Tinian, and Rota represents a very small labor force compared to the 39,000 Japanese civilians formerly on the three islands. Moreover, these islands represent the bulk of the available farm land.

Labor for phosphate development, fishing, and other enterprises is simply not available. More important, perhaps, is the lack of technical skill and knowledge. (Of course, the relatively few people required in this capacity could readily be imported.)

Insofar as agriculture is concerned, the problem of cultural practices is second only to that of labor supply. In the first place, laborsaving machinery cannot be used extensively. The rough and varied character of the land, the frequency of rainfall, and the rapid growth of weeds make large amounts of hand labor indispensable. Erosion is extremely rapid where land having the slightest slope is cultivated in "large" areas. The clean cultivation of papaya orchards on Saipan and Guam during the past few years gave emphasis to this fact. The native and Japanese methods of culture are not so conducive to erosion; they cultivate in small plots, with successive plot divisions planted to bananas, Napier grass, and other erosion-resisting plantings.

Although adequate saline-free water supplies have been developed by the armed services for occupational uses, supplies are not available for irrigation during the dry season. This limits the intensity of production. Some of the smaller islands, particularly those of coral origin, have no fresh water available to them.

In spite of DDT spraying, insects are severe handicaps to production. Among the more important insect pests are the European corn borer, corn earworm, aphids, leaf hoppers, and the coconut scale. The lack of seasonal climatic changes and the frequency of rainfall make control measures difficult. Almost continuous spraying is necessary for combating both sucking and chewing insects.

Plant diseases are no less troublesome, especially bacterial and fusarium wilts of tomatoes and downy mildew on beans and cucurbits. Resistant and acclimated varieties are needed. For example, the only varieties of cantaloupe available for subsistence gardens were thin-skinned and quickly susceptible to bacterial rot. Consequently, cantaloupe could not be allowed to ripen. Thick-skinned varieties would help to overcome this trouble.

Animal parasites and diseases are prevalent everywhere. Intestinal and stomach worms, pneumonia, liver and lung flukes, are serious menaces to poultry, hogs, and cattle. Goats seem to be comparatively free from these pests. The natives are nonetheless free from hookworm and other intestinal worms.

Another acute livestock production problem is the general lack of suitable pasture. Native cattle are constantly vulnerable to fluke infestations by reason of their dependence on swampy lowlands, especially during the dry seasons. The Japanese made no attempts to establish suitable pastures, depending mainly on wild vegetation and plant refuse for feed. With the establishment of a 75-cow dairy on Guam, the U. S. Commercial Company ran into this problem. It later attempted to provide some grazing by planting certain large stem grasses, the success of which has not been reported. It will be difficult to maintain upland pastures during the dry seasons, and lowland pastures are constantly subject to fluke infestation.

Most crops need moderate applications of fertilizer. The soils of the volcanic islands, if thoroughly weathered and

with a substantial organic content, will produce certain crops without fertilizer; but satisfactory yields of suitable quality require medium amounts of a complete fertilizer. Fertilizers used for vegetable production should be relatively low in nitrogen and high in potash and phosphorus. High nitrogen applications combined with the very rapid normal growth tend to produce excessive vines and foliage rather than fruit and roots.

A thorough understanding of, and an appreciation for, local conditions and requirements are essential to successful farming in these islands. Fortunately, the Guam Agricultural Experiment Station has placed on record, as annual reports from 1909 to 1932, a considerable amount of experimental knowledge that should be helpful in future farming endeavors. If this store of knowledge had been used as a guide to the food production programs during the past two years, much greater success might have been experienced. Certainly, the insistence on using highly bred varieties of seed corn from the United States, rather than a tried and proven "Guam Acclimated" variety would have been much more productive. The wasteful practice of applying 1,000 pounds of high-analysis (12–18–12) fertilizer per acre of corn and the importation of large quantities of useless heavy farm machinery might have been avoided. The provision of more than 60 farm tractors, during the war, to farm four or five hundred acres of land on Guam is an example. Such citations could be duplicated severalfold.

In conclusion, certain opportunities for resource development in the Marshalls, Carolines, and the Marianas appear more or less feasible. Copra and phosphate probably offer the most immediate possibilities. Even they may depend on the importation of labor, supplies, and satisfactory knowledge. The abandoned sugar cane, the major Japanese interest, is of little potential value, except that small portions may be rehabilitated to supply the natives with molasses and sugar. It is doubtful that the Japanese or Chinese will ever be given access to redevelop this source of sugar supply. Fishing in the surrounding waters certainly should be possible, if this area offers advantages, thus enhancing food supplies in this sector of the world.

There seems to be no reason why the United States should subsidize resource development beyond that necessary to fulfill our obligations to the natives. Even the feasibility of subsisting our military forces from the islands would be questionable. Continental interests, the demand for food of high quality, and the increasing adequacy of seagoing refrigeration make local dairying, hog farming, and vegetable production questionable ventures. The fact that nearly all necessary supplies can be imported at no greater expense than the cost of production on the islands is a good reason why local investments are likely to be comparative failures. Obviously, this is not to say that highly perishable fruits and vegetables should not be produced in family gardens. Nor is there any reason why native farmers should not be encouraged to produce fresh corn, native fruits, and vegetables of a quality suitable for supplementing imported food supplies.

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MATHEMATICAL ALLUSIONS IN POE

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IT CANNOT well be denied that the prose works of Edgar Allan Poe impress the average reader as possessing a decidedly mathematical quality. In the first place, the remarkable precision of expression which was Poe's habitual style and in which, in fact, he took a conscious pride, suggests strongly, though quite irrelevantly, the austere and rigorous formulation of a mathematical argument. Second, the stories for which Poe is most widely known, *The Gold Bug, The Murders in the Rue Morgue, The Purloined Letter, and The Mystery of Marie Roget,* involve in an essential way, reasoning of a "Since . . . , therefore . . ." character strikingly reminiscent of the logical structure of the demonstrations of Euclid. Finally, to a degree far surpassing that of any other literary figure of comparable stature, Poe sprinkled his stories and his essays with specific references to mathematics and to mathematicians.

It is easy to understand why this combination of style, structure, and allusion should make Poe's writings seem to possess a mathematical flavor. Whether these features justify the inference often drawn and summed up in the words of Sir Arthur Eddington in a solicited letter to Arthur Hobson Quinn, quoted in the latter's book *Edgar Allan Poe*—"Poe, besides being fairly well informed in science and mathematics, seems to have had the mind of a mathematician . . ."—is another matter, however.

Many writers who by no stretch of the imagination could be termed mathematically inclined have written with great lucidity and precision. Likewise many a well-constructed detective story has been spun by authors to whom mathematics was nothing more than a vague recollection of dreary formulas and headaches. It thus seems clear that the real evidence bearing on Poe's familiarity with, and appreciation of, mathematical thought is to be found in his references, both direct and implicit, to mathematical topics; and this is the point of view we shall adopt here.

We shall not attempt to be exhaustive in our review of the mathematical allusions in Poe, for it is not our intention to compile a concordance of the technical terms to be found in his work. Our purpose is rather to discover the general nature of the mathematical references a great writer saw fit to employ, to observe their aptness as illustrations and their usefulness to him in creating effects, and to examine their significance as indications of his grasp of mathematical ideas. If some of our conclusions on the last point seem a bit severe we can console ourselves with the reflection that should our criticisms demonstrate that there is no reasonable basis for attributing any real mathematical insight to Poe, then his lapses from mathematical rectitude cannot properly be held against him. And in thus making conviction tantamount to acquittal, surely we do him no disservice.

Let us begin with some of the casual and more ornamental of the allusions, keeping in mind that as evidence bearing on our central question they are in general equivocal and of significance only if they are faulty, since almost all of them relate to quite elementary matters familiar, at least as names, to anyone who, in Poe's own words,

. . . possessed at one time . . . the average quantum of American collegiate lore—"a little Latin and less Greek," a smattering of physical and metaphysical science, and . . . a *very* little of the mathematics (Nathaniel Parker Willis in *The Literati of New York*).

Sometimes Poe refers to mathematical topics to epitomize complexity and obscurity. For instance, in *William Wilson* in the description of the old house he writes that

. . . the lateral branches were innumerable—inconceivable—and so returning in upon themselves that our most exact ideas in regard to the whole mansion were not very far different from those with which we pondered upon infinity.

And in a note in *Marginalia* he says:

Here is a plot which with all its complexity has no adaptation, no dependency:—it is involute and nothing more—having all the air of . . . the cycles and epicycles in Ptolemy's "Almagest."

And in *The American Drama* in discussing the typical critic,

He delights in mystery—revels in mystification . . . and talks about "stage business" and "stage effects" as if he were discussing the differential calculus.

That these quotations do not represent Poe's settled convictions is evident when they are contrasted with others of contradictory force. For example,

It is merely because a stepping stone here and there is needlessly left unsupplied in our road to differential calculus that this latter is not altogether as simple a thing as a sonnet by Mr. Solomon Seesaw (*Eureka*).

And in *The Rationale of Verse* we are told that

. . . the subject [versification] is exceedingly simple; one-tenth of it, possibly, may be called ethical; nine-tenths however appertains to mathematics, and the whole is included within the limits of the commonest common sense.

In extension of this idea Poe asserts in another place:

The highest order of the imaginative intellect is always preeminently mathematical, and the converse (*The Poets and Poetry of America*).

Frequently Poe's references are of a studied pseudoseriousness that is quite humorous. For instance, in describing the reaction of the citizens of Alexander-the-Great-onopolis to a newspaper article in which every *o* was replaced by an *x* because a rival printer had made off with all the *o*'s in the editor's font, Poe writes:

The more common conclusion, however, was that the affair was simply *X*-traordinary and in-*X*-plicable. Even the town mathematician confessed that he could make nothing of so dark a problem. *X*, everybody knew was an unknown quantity, but in this case (as he properly observed) there was an unknown quantity of *X* (*X-ing a Paragrab*).

Another in the same spirit occurs in *The Devil in the Belfry:*

Of the date of this origin [of the town of Vondervatteimittis] I grieve that I can only speak with that species of indefinite definiteness which mathematicians are at times forced to put up with in certain algebraic formulas. The date, I may thus say, in regard to the remoteness of its antiquity, cannot be less than any assignable quantity whatsoever.

And again in *Some Secrets of the Magazine Printing House:*

These publishers pay *something*—other publishers nothing at all. Here certainly is a difference—although to a mathematician it might be infinitesimally small.

A more factual example of this type appears in another note in *Marginalia:*

On the back of the book is a monogram . . . whose solution is a fertile source of trouble with all readers. This monogram is a triangular pyramid; and as in geometry the solidity of every polyhedral body may be computed by dividing the body into pyramids, the pyramid is thus considered as the base or essence of every polyhedron. The author, then . . . may mean to imply that his book is the basis of all solidity or wisdom—or perhaps since the polyhedron is not only a solid but a solid terminated by *plane faces*, that the "Doctor" is the very essence of all that spurious wisdom which will terminate in just nothing at all.

As a final example of this sort here is a quip that I confess I find quite amusing:

To speak algebraically: Mr. M. [Cornelius Mathews] is execrable but Mr. C. [William Ellery Channing] is $(x+1)$-ecrable (*James Russell Lowell*).

On occasion the allusions are quite apt figures of speech: "The mere succession of incidents, even the most spirited, will no more constitute a plot than a multiplication of zeros, even the most infinite, will result in the production of a unit" (*The American Drama*). However, it is likely that a person with any real feeling for mathematics would have substituted "addition" for "multiplication," since it should be clear that the multiplication of zeros involves no tendency toward unity, whereas the unlimited addition of zeros might well suggest to a naive mind an equally fallacious approach to magnitude. The latter rather than the former is thus the metaphorical equivalent of Mr. Willis' theory of plot construction.

In his essay *Cryptography* Poe discusses the ancient cryptographic device of the scytale, in which the message is written in the axial direction on a strip of parchment wound spirally on a cylinder, an exact duplicate of which is in the hands of the recipient of the message, and bases his scheme for finding the diameter of the cylinder and thus "breaking" the code upon the use of a cone around which at various stations the strip bearing the communication may tentatively be coiled. For in his words, "As in passing up the cone to its apex all possible diameters are passed over, there is no chance of failure." This shows some insight, perhaps, into the nature of continuity, but lest we here attribute too much credit to Poe, let us observe that the average teacher of advanced calculus usually has less difficulty making his students understand the proof of the theorem that "a function continuous over an interval takes on at least once within the interval every value between those which it assumes at the end points" than he does in convincing them that so obvious a result needs proof at all. Moreover, this property was known for a long time before Poe's day. In fact, he gives it all away himself in another of the fragments in *Marginalia:*

> This reasoning is about as convincing as would be that of a traveller who, going from Maryland to New York without entering Pennsylvania, should advance this feat as an argument against Leibnitz' Law of Continuity according to which nothing passes from one state to another without passing through all the intermediate states.

One cannot say with certainty whether this isolated note was intended as a serious comment on some argument Poe thought faulty, or whether it was jotted down as a pun on the word "state," though the latter is perhaps nearer the truth. In any event it reveals the probable source of Poe's knowledge of the theorem in question.

Of all his literary applications of mathematics, the one that seems to me most complimentary to Poe occurs in *Hans Pfaall* and again almost word for word in *The Balloon Hoax:*

> What mainly astonished me in the appearance of things below was the seeming concavity of the surface of the globe. I had thoughtlessly enough expected to see its real convexity become evident as I ascended; but a very little reflection sufficed to explain the discrepancy. A line dropped from my position perpendicularly to the earth would have formed the perpendicular of a right angled triangle of which the base would have extended from the right angle to the horizon, and the hypotenuse from the horizon to my position. But my height was little or nothing in comparison with my prospect. In other words the base and hypotenuse of the supposed triangle would have been so long when compared to the perpendicular that the two former might have been regarded as nearly parallel. In this manner the horizon of the aeronaut appears always to be upon a level with the car. But as the point immediately beneath him seems and is at a great distance below him, it seems also at a great distance below the horizon. Hence the impression of concavity; and this impression must remain until the elevation shall bear so great a proportion to the prospect that the apparent parallelism of the base and hypotenuse disappears.

This is well done and quite effective in maintaining the desired air of scientific accuracy in the development of the narrative. If it was original with Poe it

demonstrates that his limited training in geometry was surely not all lost.

Not all his references, however, can even with charity be appraised as favorably as the last pair. Further on in *Hans Pfaall* we find, for instance,

> The balloon had now . . . reached a height of *not less* certainly than 7254 miles above the surface of the sea. . . . At all events I undoubtedly beheld the whole of the earth's major diameter; the entire northern hemisphere lay beneath me like a chart orthographically projected, and the great circle of the equator itself formed the boundary line of my horizon.

This of course is false since from no finite distance can as much as half the surface of a sphere be surveyed. Later in the same story appears the assertion,

> The form of the moon's orbit being an ellipse of eccentricity amounting to no less than 0.05484 of the major semi axis of the ellipse itself, and the earth's center being situated in its focus. . . .

In this, although the decimal itself is correct, there is a fundamental misconception that cannot be argued away as mere hyperbole, the way any author but one hampered by a desire to pose as a mathematician might explain the previous quotation, for the eccentricity of an ellipse is not expressed as a fraction of the major axis of the figure at all. In fact, it is not a length of any description but a dimensionless combination of both the semimajor and semiminor axes, a and b, respectively, defined by the expression

$$\text{eccentricity} = \frac{\sqrt{a^2 - b^2}}{a}.$$

And in *The Purloined Letter*, at the end of a long passage on the limitations of mathematical thought to which we shall return in our discussion of Poe's attitude toward axioms, we are told:

> In short, I never yet encountered the mere mathematician who could be trusted out of equal roots, or who did not clandestinely hold it as a point of his faith that $x^2 + px$ was absolutely and unconditionally equal to q. Say to one of these gentlemen by way of experiment if you please that you believe occasions may occur where $x^2 + px$ is not altogether equal to q, and having made him understand what you mean, get out of his reach as speedily as convenient, for beyond doubt he will endeavour to knock you down.

Here, again is confusion. Of course "$x^2 + px$ is not altogether equal to q." In fact, it is almost never equal to q, being so for, at most, two values of x, and no mathematician or mathematical dilettante ever held the opposite view. What Poe did here in setting up his straw man was to project upon mathematicians his own uncertainty regarding the elementary distinction between an identity and an equation.

Poe frequently refers to Newton's *Principia*, but it is reasonable to question how much of it was in any sense intelligible to him in view of his misconception of so fundamental a matter as Newton's second law of motion. In several different places he makes the following statement. (We take the wording from *The Purloined Letter* again, for the lengthy passage from which we have quoted is sometimes cited as evidence of Poe's relative scientific maturity. *Cf.* Quinn, *loc. cit.*, 421.)

> The principle of the *vis inertia* for example seems to be identical in physics and metaphysics. It is not more true in the former that a large body is with more difficulty set in motion, and that its subsequent momentum is commensurate with this difficulty, than it is in the latter that intellects of vaster capacity . . . are yet the less readily moved.

If the figure of speech is good, it is at the expense of the mathematics and physics of the proposition for it is easy to show that the momentum of a body set in motion by a given force is not in general proportional to its mass. In particular, in the obvious special case in which the force is a constant independent of the mass, the momentum is likewise entirely independent of the mass, the greater resultant velocities of lighter bodies in such cases exactly compensating for what would otherwise be the defect in their momenta occasioned by their lesser masses.

An especially revealing passage is found in *Cryptography:*

> In any of the ordinary books upon algebra will be found a very concise *formula* (we have not the necessary type for its insertion here) for ascertaining the number of arrangements in which m letters may be placed n at a time.

Poe could hardly have given himself away more completely, for the formula defining the number of permutations of m things taken n at a time is one of the simplest of all algebraic formulas to write and one of the few that do not require any special type. For instance, it might have been written in the notation preferred by the English-speaking mathematicians of Poe's day in the form

$$\frac{m(m-1)(m-2)\ \ldots\ 3.2.1}{(m-n)(m-n-1)\ \ldots\ 3.2.1}$$

or, had as little as one + sign been available,

$$m(m-1)(m-2)\ \ldots\ (m-n+1).$$

The still more compact forms preferred by the continental mathematicians,

$$\frac{m!}{(m-n)!} \quad \text{and} \quad \frac{\lfloor m}{\lfloor m-n},$$

which were perhaps the ones Poe had vaguely in mind, could likewise have been set up in type without employing any symbols not actually used later on in the essay itself. It is hard to shake off the conviction that Poe was bluffing and on a point involving elementary algebra but slightly removed from "the commonest common sense."

One field of mathematics with which Poe explicitly boasted some familiarity was probability, for in one of his letters to Mrs. Sarah Helen Whitman he wrote: ". . . to one accustomed as I am to the Calculus of Probabilities. . . ." His general attitude is represented by the following typical quotations:

> Now this Calculus [probability] is in its essence, purely mathematical; and thus we have the anomaly of the most rigidly exact in science applied to the shadow and spirituality of the most intangible in speculation (*The Mystery of Marie Roget*).

> The theory of chance . . . has this remarkable peculiarity, that its truth in general is in direct proportion with its fallacy in particular (*A Chapter of Suggestions*).

> Coincidences in general are great stumbling blocks in the way of that class of thinkers who have been educated to know nothing of the theory of probabilities—that theory to which the most glorious objects of human research are indebted for the most glorious of illustrations (*Murders in the Rue Morgue*).

These all have an epigrammatic quality which it is difficult either to challenge or to accept. But there are other and more specific references that may be examined. At the conclusion of *Marie Roget* Poe cautions against assuming that the similarity between the facts in the mystery unraveled by Dupin and the facts surrounding the disappearance of the New York girl Marie Cecelia Rogers implies that the solutions of the two cases may be similar. In fact, he asserts that just because of the similarity of the data, dissimilarity of the denouements is to be expected. In his words,

> . . . the very Calculus of Probabilities . . . forbids all idea of the extension of the parallel,—forbids it with a positiveness strong and decided just in proportion as this parallel has already been long drawn and exact. This is one of those anomalous propositions which seemingly appealing to thought altogether apart from the mathematical is yet one which only the mathematician can fully entertain. Nothing for example is more difficult than to convince the merely general reader that the fact of sixes having been thrown twice in succession by a player at dice is sufficient cause for betting the largest odds that sixes will not be thrown in the third attempt. A suggestion to this effect is usually rejected by the intellect at once. It does not appear that the two throws which have been completed and which now lie absolutely in the past can have any influence upon the throw which exists only in the future. The chance for throwing sixes seems to be precisely as it was at any ordinary time—that is to say, subject only to the influence of the various other throws which may be made by the dice. And this is a reflection which appears so exceedingly obvious that attempts to controvert it are received more frequently with a derisive smile than with anything like respectful attention. The error here involved . . . I cannot pretend to expose within the limits assigned to me at present; and with the philosophical it needs no exposure.

There is of course a twofold error here. In the first place, it is mathematically incorrect to advance the thesis that a long run of successes augurs strongly a failure on the next turn. To put it picturesquely, this is equivalent to personifying probability and endowing it with an intelligence (akin no doubt to that of Maxwell's demon doorkeeper, which is able to abrogate the second law of thermodynamics) so that it can "keep books" on the trend of the game and exert a continuous restoring influence toward the expected frequency of successes. Actually, there are only two logical ways to estimate what may happen on the next turn after a long succession of favorable trials. One is to do what Poe describes accurately but rejects, namely, to retain confidence in the original analysis, or assumption, of the probability and accept the inescapable conclusion that the chance of an additional success is exactly the same no matter what has happened on previous turns. The other is to revise the analysis in the light of the recent experimental evidence, in which case the chance of a further success is greater, not less, than it was.

The second error in the passage is a psychological one, namely, the assertion that most people are hard to convince that a failure is more than usually probable after a number of successes. Generation after generation of freshmen study the fundamentals of probability in college algebra, and the majority of those who make mistakes make just the mistake Poe did, an error so frequent that it has actually been given a name, the Gambler's Fallacy. Considering Poe's usually acute psychological insight, it is hard to understand how he came to make this second error, for surely human nature has not changed that much in one hundred years.

There remains one broad class of allusions that it is extremely interesting to explore. This contains Poe's numerous references to axioms, self-evidence, consistency, and related topics from the area which mathematics and logic share with one another. Here if anywhere a person with a mathematical mind, with or without extensive formal training, should have revealed that ability. But let us examine the record.

In places it seems that Poe was surprisingly modern. For instance, in the passage in *The Purloined Letter* from which we have already quoted, he makes Dupin say,

> The great error lies in supposing that even the truths of what is called *pure* algebra are abstract or general truths. . . . Mathematical axioms are not axioms of general truth.

And in *Eureka,* Poe's major excursion into cosmology, he writes,

> . . . as for self-evidence, there is no such thing. . . .

A little later he amplifies this assertion, declaring,

> Now it is clear not only that what is obvious to one mind may not be obvious to another, but that what is obvious to one mind at one epoch may be anything but obvious at another epoch to the same mind. It is clear moreover that what today is obvious even to the majority of mankind or to the majority of the best intellects of mankind may tomorrow be to either majority more or less obvious, or in no respect obvious at all. It is seen then that the axiomatic principle itself is susceptible of variation, and of course that axioms are susceptible of similar change. Being mutable, the truths which grow out of them are necessarily mutable, too. . . .

On the basis of quotations such as these, Dr. Paul Heyl in another solicited letter to Prof. Quinn credits Poe with an early and independent recognition of the fact, first made clear in the work of Bolyai and Lobatchewsky on hyperbolic non-Euclidean geometry, that the axioms of geometry are not self-evident truths.

Had Poe stopped with these rational and essentially modern observations it would be easy to let the compliment stand, but he did not. When it suited his purpose (as it frequently did) both before and after the above passages were written, axioms were still self-evident

truths. For example, in his essay on *Charles Dickens* he wrote (1842):

> Excellence may be considered an axiom, or a proposition which becomes self-evident just in proportion to the clearness or precision with which it is put. . . . It is not excellence if it need be demonstrated as such.

Later (1848) he repeated this thought almost word for word in *The Poetic Principle* and, with "beauty" substituted for "excellence," in *Critics and Criticism*. Even in *Eureka* he wavers:

> Now the laws of irradiation are *known*. They are part and parcel of the *sphere*. They belong to the class of *indisputable geometric properties*. [The italics are Poe's.] We say of them, "They are true, they are evident." To demand why they are true would be to demand *why* the axioms are true upon which their demonstration is based.

Before overlooking these contrary opinions and crediting Poe with nonetheless possessing the modern viewpoint, let us examine what inferences he drew from his occasional denials of self-evidence. The proper conclusion is that axioms being not necessarily self-evident or "inescapable" are therefore relatively arbitrary, that is, much more numerous than they otherwise would be, thereby making possible the coexistence of mutually incompatible but self-consistent doctrines. Poe reached no such conclusion. His denial of the traditional view was complete and utter and illogical. Because self-evidence could not validate an axiom, there were no axioms at all, demonstration was impossible, and truth rose out of intuition (the difference between which and individual or personal self-evidence Poe never made clear) in one blinding flash in which simultaneously premises and conclusions had their origin. Again and again in *Eureka* these ideas find expression:

> No such things as axioms ever existed or can possibly exist at all.
>
> Whatever the mathematicians may assert, there is in this world no such thing as demonstration.
>
> We have reached a point where only intuition can aid us.

To explain away this view by urging that Poe's real argument involved defining axioms as self-evident truths and then showing this class to be vacuous is hardly warranted in the light not only of some of the quotations we have already given, but also in the light of his wholehearted acceptance of the doctrine of John Stuart Mill that "ability or inability to conceive is in no case to be received as a criterion of axiomatic truth."

In both *Eureka* and in *Mellonta Tauta* Poe attacked Mill for his supposed violation of this principle in accepting the law of the excluded middle, and again in setting up a straw man revealed the confused state of his own ideas. He claimed that Mill accepted the principle of the excluded middle solely because he could not conceive of things being otherwise, which superficially does appear to contradict the "principle of conceivability." This shows clearly that Poe did not realize that axioms are axioms simply because someone declares they are and uses them in his subsequent discussion as such. The law of the excluded middle is in the modern sense an axiom of logic, and the fact that it appears self-evident and that most people cannot imagine it false neither proves it true nor yet renders it unacceptable as a postulate.

The lengthy passage in which Poe presents this attack on Mill should be studied by every embryonic debater. It is a brilliant example of a spurious but highly effective *reductio ad absurdum* of an opponent's position. Quinn and others regard it as a bizarre bit of humor inserted at the beginning of *Eureka*, perhaps in deference to the ageless tradition that every speech (*Eureka* was actually a lecture which Poe gave on various occasions) should begin with a witticism. However, it seems more reasonable to take it seriously and to suppose that Poe was aware of the forensic value of this attack on the methods of classical logic and, realizing further that his own remarks were obscure and

inconsistent in many places, that is, that they were at best prose-poetry and not science, chose this introduction to stifle logical objections by holding logic up to preliminary ridicule.

Since Poe entertained such uncertain ideas about axioms, it was only to be expected that his notions of the related matters of proof, truth, and consistency would be equally cloudy. We have already observed that he frequently denied the existence of rigorous demonstrations, yet he was quite willing to assert the absolute character of a mathematical proof if the occasion required it. Thus in *The Domain of Arnheim* he declares that "the mathematics afford no more absolute demonstrations than the sentiments of his art yield the artist." And in *Eureka* itself he goes so far as to compliment himself because his reasoning compares favorably with that of Euclid: "I maintain, secondly, that these conditions have been imposed upon me as necessities in a train of ratiocination *as rigorously logical as that which establishes any demonstration in Euclid.*" (The italics are Poe's.)

For Poe absolute truths exist with consistency as their warrant, for he says in *Eureka:* "A thing is consistent in the ratio of its truth—true in the ratio of its consistency. *A perfect consistency, I repeat, can be nothing but an absolute truth.*" (The italics again are Poe's.) Leaving aside the vexing and still unanswered question of how "perfect consistency" can be inferred, the idea that consistency or anything else can establish an absolute truth is strangely out of place among reputedly modern ideas.

Perhaps following Keats and the "truth-beauty, beauty-truth" philosophy of his *Ode on a Grecian Urn*, Poe likewise made beauty a basis for truth. After an extended description of the nebular hypothesis of Laplace, he declares (*Eureka*): "From whatever point we regard it we shall find it *beautifully* true. It is by far too beautiful, indeed *not* to possess Truth as its essentiality—and here I am profoundly serious in what I say."

A third and most remarkable basis for belief is complexity. Still discussing the nebular hypothesis, Poe says, "I may as well here observe that the force of conviction in cases such as this, will always with the right thinking be proportional to the amount of complexity intervening between the hypothesis and the result."

In quoting from *Eureka* as extensively as we have in the last paragraphs, we have not been unfair to Poe, for the arguments of the essay are the ones advanced by the protagonists of Poe, the scientific dreamer, as evidence of his prevision of modern astronomical theories, and Poe himself realized that it should be perfect and unassailable, for he wrote in a letter to Mrs. Jane Locke: "But for duties that just now *will not* be neglected or even postponed—the proof reading of a work of scientific detail [*Eureka*] in which a trivial error would involve me in very serious embarrassment—I would ere this have been in Lowell."

To probe deeper into the detailed arguments of *Eureka* would be an interesting but overwhelming task, and one to which the talents of a physicist or an astronomer were better suited than those of a mathematician. Moreover, the thing has been done to a degree by critics trying to decide whether or not the grandiose ideas of the origin of the universe contained in the essay indicate any weakening of Poe's admittedly unstable mind. My own feeling, shared I think by most critics, is that the minor confusions we have noted are representative of the state of the whole, and that if one reads it as scientific speculation it is impossible to escape the conviction that most of its quantitative statements are inaccurate and many of its descriptive passages highly ambiguous or mutually contradictory. Its essentially unscientific character may well be epitomized by apposing the following pair of quotations:

Each law of Nature is dependent at all points upon all other laws.

It is an admitted principle in Dynamics that every body on receiving an impulse or disposition to move will move onward in a straight line in the direction imparted by the impelling force until deflected or stopped by some other force. How then, it may be asked, is my first or external stratum of atoms to be understood as discontinuing their movement at the circumference of the imaginary glass sphere when no second force of more than an imaginary character appears to account for the discontinuance?

I reply that the objection in this case actually does arise out of an "unwarranted assumption" on the part of the objector, the assumption of a principle in Dynamics at an epoch when no "principles" in anything exist.

Can it be science or the work of a mathematically inclined mind when that mind alone can say when laws are operative and when they are not, when forces act and when they do not, and when criticism is stifled by the arbitrary dictum that the physical principle advanced in support of an objection was not at that time valid, although half a dozen similar laws may have been invoked previously in the construction of the argument?

Eureka should not be judged by false standards, but read simply as a metaphysical prose-poem. And if we must relate it to similar ventures of the restless mind of man let us not read into it an anticipation of the expanding universe of the modern relativists, but let us simultaneously acknowledge Poe's scientific limitations and his known indebtedness to such German orientalists as Schelling, Fichte, and the two Schlegels and regard it more reasonably as his paraphrase of the central philosophy of the *Vedas*, the *Upanishads*, and the *Vedanta* of the Indians, as Prof. Forrest has pointed out in his book *Biblical Allusions in Poe*.

From the nature and frequency of his mistakes and misconceptions, both in *Eureka* where critics have for long been cognizant of them, and in his other essays where they have been less frequently remarked, it seems abundantly clear that Poe was not a poor mathematician but simply no mathematician at all. And of course there was no reason why he should have been. He took no mathematical courses during his brief stay at the University of Virginia, and while he did pursue mathematical studies at West Point it was only a few months before they terminated with his court-martial and dismissal. During his mature years when he had to labor unceasingly to gain the bare necessities of life it is doubtful that he had any time for study, although his familiarity with names and topics shows that he did a commendable amount of "browsing" in technical works.

As a person with respectable mathematical inclinations, rooted in a reasonable appreciation of the subject, Poe would naturally have ornamented his work with allusions from the field. As a nonmathematician his reason for such embellishment is more obscure, and has confounded some commentators into inferring ability on very superficial evidence. The real explanation probably lies deep in the processes of Poe's peculiar mind. A psychoanalytical theory of what might be called "Poe's legend of himself," well conceived and brilliantly written is to be found in the book *Edgar Allan Poe—A Study in Genius* by Joseph Wood Krutch. Although Poe's most recent, and perhaps most scholarly biographer, Quinn, rejects completely the Freudian approach of Krutch, it appeals to me as a reasonable analysis of Poe's personal and literary characteristics, and one which in particular is quite adequate to explain Poe's posturing with the most esoteric discipline of which he had any knowledge, mathematics.

BOOK REVIEWS

SCIENCE BOOKS FOR THE NONSCIENTIST

GOOD science makes good reading. Unfortunately, too many nonscientists—and some scientists—nurtured on stilted science textbooks, have not yet become acquainted with this mind-warming fact. The scientific classics molder on library shelves because the average reader, who voraciously devours biographies, does not know that many of the great scientific books are in large part warm and thrilling biographies of outstanding men of science. The lives of men like Newton, Darwin, Galileo, and the like are in their works.

In re-exploring scientific literature for its literary merit, I have turned up an incredible amount of material that is good reading as well as good science. Much of this material is to be found in an average library—but it does not circulate nearly as much as it should. There is a certain fear on the part of many nonscientists that they will neither understand nor enjoy scientific literature as written by its greatest masters. Once they get a real taste of it, however, they cannot get enough of it. The taste is easier to acquire than a liking for ripe olives or raw oysters.

The study of science as a cultural subject rather than a purely technical or mechanical one is growing and can be expected to continue growing. Many colleges are now introducing broad orientation courses in science for students who are not candidates for science degrees. Yale College, for example, is introducing such a course this year. The library can do a great deal to enrich the lives of many out-of-college individuals by acquainting them with books that make it possible to understand science as a way of life and thought and not merely a hobby.

To further the study of science as a cultural subject, I suggest that the following recommendations be made to librarians:

1. Do not segregate all the scientific classics among technical books. If the library has open "browsing" shelves, put some of the science books under "biography," "travel," and "essays." Descartes' "Discourse on Method," Benjamin Franklin's experiments on electricity, John Snow's "On Cholera," Langley's "Memoir on Mechanical Flight," and Faraday's diary are as much biography as they are science.

2. Keep and display science source books and anthologies. They will develop a taste for further reading. (And, incidentally, they make a wonderfully convenient shelf of reference books for the quick answer to many scientific questions.) The list of science source books given below should serve the needs of many libraries:

BAITSELL, GEORGE (editor). *Science in Progress* (1st, 2nd, 3rd, and 4th Series). New Haven: Yale University Press. 1945.

BEEBE, WILLIAM (editor). *The Book of Naturalists, An Anthology of the Best Natural History.* New York: Alfred A. Knopf. 1944.

CLENDENING, LOGAN (compiler). *Source Book of Medical History.* New York and London: Paul B. Hoeber, Inc. Harper & Brothers. 1942.

CULLIMORE, ALLAN R. (editor). *Through Engineering Eyes, Science Selections from Literature.* (Re-edited by Frank A. Grammer and James H. Pitman.) New York and Chicago: Pitman Publishing Corporation. 1941.

DAMPIER-WHETHAM, SIR W. C., and WHETHAM, MARGARET D. (arrangers). *Cambridge Readings in the Literature of Science.* New York: The Macmillan Company. 1924.

ELIOT, CHARLES W. (editor). *Harvard Classics, Vol. 38, Scientific Papers.* New York. 1897.

FULTON, JOHN F. (editor). *Selected Readings in the History of Physiology.* Springfield (Ill.): Charles C. Thomas. 1930.

KNICKERBOCKER, W. S. (editor). *Classics of Modern Science (Copernicus to Pasteur).* New York: Alfred A. Knopf. 1927.

LAW, FREDERICK HOUK (editor). *Science in Literature, A Collection of Literary Scientific Essays.* New York and London: Harper & Brothers. 1929.

LONG, E. R. (editor). *Selected Readings in Pathology from Hippocrates to Virchow.* Springfield: Charles C. Thomas. 1929.

MAGIE, WILLIAM FRANCIS (editor). *A Source Book in Physics.* New York and London: McGraw-Hill Book Company, Inc. 1935.

MAJOR, RALPH H. (editor). *Classic Descriptions of Disease.* Springfield: Charles C. Thomas. 1932.

MATHER, KIRTLEY F., and MASON, SHIRLEY L. (editors). *A Source Book in Geology.* New York and London: McGraw-Hill Book Company, Inc. 1939.

MOULTON, FOREST RAY, and SCHIFFERES, JUSTUS J. (editors). *The Autobiography of Science.* New York: Doubleday, Doran, Inc. 1945.

RATCLIFF, J. D. (editor). *Science Yearbooks,* 1943, 1944, 1945. New York: Doubleday, Doran and Company. 1943–45.

SHAPLEY, HARLOW, and HOWARTH, HELEN E. (editors). *A Source Book in Astronomy.* New York and London: McGraw-Hill Book Company, Inc. 1929.

———, RAPPORT, SAMUEL, and WRIGHT, HELEN (editors). *A Treasury of Science.* New York and London: Harper & Brothers. 1943.

SMITH, DAVID EUGENE (editor). *A Source Book in Mathematics.* New York and London: McGraw-Hill Book Company, Inc. 1929.

THOMS, HERBERT (editor). *Classical Contributions to Obstetrics and Gynecology.* Springfield: Charles C. Thomas. 1935.

WILLIUS, F. A., and KEYS, T. E. (editors). *Cardiac Classics.* St. Louis: C. V. Mosby Company. 1941.

3. Have simple exhibits of science books. Almost every year affords an "occasion" for the display of a book and a portrait of a great scientist. For example, 1943 was the four hundredth anniversary of the publication of Copernicus' famous *Revolution of the Heavenly Bodies* in the year of his death, 1543. 1945 was the hundredth anniversary of the birth of Wilhelm Konrad Roentgen and the fiftieth anniversary (on December 28) of his world-shaking announcement of the discovery of the X-ray. Excellent newsworthy exhibits would have been easy to construct on an "X-ray" theme. For the library that has fuller resources, the following display exhibit might well serve to call attention to its wealth of science-as-culture material:

The Ten Most Important Books in the History of Science

The underlying purpose of this exhibit is to reveal the correlation between the graphic arts—with special reference to printed *books*—and the development of scientific thought. Scientific development has gone forward through an interaction between observation and hypothesis, between things and thoughts, between instruments and ideas, between tools of experiment (e.g., microscope, telescope, electromagnet, air foil) and preservation of ideas in printed form. This exhibit places emphasis on those great ideas—such as the heliocentric universe and the origin of species—which were presented to, and preserved for, the world of scientific thinking in the form of *books*.

The lodestone of the exhibit should be the original editions, under glass, of the following books which were turning points in the history of science:

1. *De Revolutionibus Orbium Coelestium* (The Revolution of Heavenly Bodies). 1543. NICOLAUS COPERNICUS (1473–1543).
2. *De Humani Corporis Fabrica* (The Anatomy of the Human Body). (Seven volumes and an Epitome.) 1543. ANDREAS VESALIUS (1514–1564).
3. *Novum Organum* (The New Atlantis). 1620. FRANCIS BACON (Lord Verulam) (1561–1626).
4. *Exercitatio de Motu Cordis et Sanguinis* (Essay on the Motion of Heart and Blood). 1628. WILLIAM HARVEY (1578–1657).
5. *Discours de la Méthode* (Discourse on Method). 1637. RÉNÉ DESCARTES (1596–1650).

6. *Principia Mathematica Philosophiae Naturalis* (The Mathematical Principles of Natural Philosophy). 1687. SIR ISAAC NEWTON (1642–1727).

7. *Inquiry into the Cause and Effects of the Variolae Vaccinae.* 1798. EDWARD JENNER (1749–1823).

8. *An Essay on the Principle of Population.* 1798. THOMAS MALTHUS (1766–1834).

9. *On the Origin of Species by Means of Natural Selection.* 1859. CHARLES DARWIN (1809–1882).

10. ..... (Visitor's Choice).

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NEW YORK, N. Y.

DESTROYED BY HIS FRIENDS

Luther Burbank, A Victim of Hero Worship. Walter L. Howard. 221 pp. Illus. $3.75. Chronica Botanica Co. Waltham, Mass. 1946.

WRITTEN by a leading horticulturist, this is the first book about Burbank that gives authentic information fairly and without prejudice. Much biographical material has been gathered from many sources. For the first time Burbank is placed in his proper background, making him a man rather than a legendary figure.

Any writer about Burbank and his work has the difficult task of sifting the exaggerated claims and misstatements arising both from Burbank's uncritical estimate of his work and the publications of writers who knew little or nothing about the scientific aspects of the subject. On the other hand, there is the overly-critical attitude of specialists in the seed and nursery trade and professional geneticists and biologists, who properly resent and distrust the nonsense about Burbank that has been too prevalent in the popular press. The background and setting of the conflicting interests that swirled about Burbank during the latter part of his life make the real accomplishments of a long life of hard work begin to stand out. The author states that he has endeavored to write a human interest story, and in this he has succeeded admirably.

Burbank is unique in that he is perhaps the only man who has tried to make a living out of plant breeding as an enterprise, separate from a seed and nursery business. Even he found this to be impossible, as in later years his income came more and more from the sale of standard varieties of seeds and plants. Without formal schooling beyond high school, Burbank became interested in this new field partly through contact with Professor Agassiz, of Harvard, who visited his father in their home at Lancaster, Mass., and partly through the writings of Darwin. A lucky find of a valuable potato seedling started him in the search for new kinds of plants that he was to pursue all his life.

The author points out that Burbank's chief difficulty was with the popular press and enthusiastic friends who made fairy stories out of his accomplishments. Burbank himself had an exaggeration coefficient of about ten and apparently made no attempt to hold within reason the imagination of writers even more gifted than he along this line.

When due allowance is made for all the extravagant statements and misinformation, there is real accomplishment, not in the science of genetics, but in the art of plant improvement. A list of Burbank products included in this book, condensed from *Bulletin 691* of the California Experiment Station by the same writer, is impressive. Horticulturists would like to see a comparison with other workers in the same field. Many specialists working with more restricted materials have accomplished more than Burbank, but no one has given this work more widespread publicity.

The author believes that professional biologists have been unjustly critical of Burbank because he was not an orthodox scientist who followed the rules for experimental procedure and publication in

scientific journals, and also that there is a certain amount of professional jealousy. The reviewer considers that any prejudice that may exist is due more to the unfair comparison that has been made with other workers in the same field who have accomplished more of lasting value than Burbank. Darwin, Mendel, and Galton were not professional investigators, but their place in the field of science is unquestioned. Although much that Burbank has done has a great deal of scientific interest and can be studied by students of heredity more than it has been, very little that he has accomplished has contributed anything to the better understanding of the laws of heredity and the principles of variation in living organisms that is fundamental to their improvement.

Every teacher and biologist interested in plant improvement will find this book a source of accurate information about one of America's most interesting and colorful figures, and it should help to correct an unfortunate attitude that has existed both on the part of the Burbank boosters as well as his detractors.

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BACTERIA OF THE OCEAN

Marine Microbiology. Claude E. ZoBell. xv + 239 pp. Chronica Botanica Co. Waltham, Mass.; G. E. Stechert and Co. New York. 1946.

THE TERM "marine microbiology," in the broadest sense, refers to all microscopic forms of life that are found in water. There have been many books concerning the protozoa and algae, but no volume especially concerned with marine bacteria, yeasts, and molds. The present volume seeks to remedy this gap, and, while it is a review primarily of bacteriological studies, the yeasts and molds also receive consideration.

Scattered over the globe are a few laboratories which specialize in the hydrobiology of inland waters and a still smaller number which are equipped for oceanic microbiology. The interests of the marine bacteriologist impinge on every phase of study which has been undertaken by the less specialized bacteriologist and include the distribution of microorganisms in water, floating plankton, and sediments; the physiology of these organisms; and their possible effect on marine ecology, industry, and public health. The curiosity of the bacteriologist concerning these studies has largely been left unsatisfied because no volume existed which organized the scientific output of the various laboratories.

Certainly none of the laboratories in the United States are unfamiliar to Dr. ZoBell, and, since there is scarcely a phase of marine bacteriology in which he has not had an active part, this versatility is reflected in the monograph. His own writings have dealt with the waters of the United States, from the steep slopes of the rising Pacific shore, through the heavy waters of Great Salt Lake and the fresh water inland lakes, to the drowned valleys of the Atlantic coast. To supplement this experience he has drawn upon the work of marine investigators in all parts of the globe. A single page of the monograph may contain references to the coastal waters of North America, the fresh or salt marshes of the Netherlands, the mud of the Dead Sea, or the Russian limans.

The inland bacteriologist approaching the field of oceanic microbiology should read attentively the chapter dealing with the difficulties of collecting samples from the sea. This should aid in the evaluation of results obtained from the studies of deep-water and bottom sediments, as well as in giving an understanding of the challenge of those vast areas as yet untouched by the sterile pipette. Since the monograph is written by a bacteriologist, some claims as

to the importance of bacteria advanced in this text will be disputed by the physical oceanographer, who is not apt to be greatly impressed by test tube experiments.

The book is of convenient size, well illustrated with comprehensible tables, and the sketches by Alma Broulik Carlin add to its interest and appearance.

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DAVID RITTENHOUSE

David Rittenhouse: Astronomer-Patriot. Edward Ford. 226 pp. $2.50. University of Pennsylvania Press. Philadelphia. 1946.

DAVID RITTENHOUSE was a truly great man. Edward Ford has proved it. And with facts only. No fiction, no glamor, no embellishment, no exaggeration, no fabrication. Just David Rittenhouse as he was. The book sustains one of my pet theories: in writing the history of a man or a nation, facts are more inviting than fiction; more impressive than fairy tales or detective stories; more thrilling than the wildest imaginations of the most modern historical novelist.

Ford has made his book interesting—at times thrilling—by telling, so appropriately, the story of Rittenhouse in words as simple, sentences as clear, and paragraphs as connected, as his life was simple, clear, and connected.

This farm boy was eight when he made a working model of a water-powered mill! He was twelve when an uncle died leaving him an English translation of the First Book of Newton's *Principia,* which changed the course of David's life away from farming (just as it had changed the course of all scientific thought throughout the world); and seventeen when he made the first Rittenhouse thirty-hour clock with works of wood! This famous clockmaker has now been dead a century and a half, yet forty of his clocks are still ticking on, still striking the hours of time. One of his famous clocks stands in the president's office of the University of Pennsylvania.

Rittenhouse was a master of many trades and occupations: a surveyor, engineer, teacher, librarian, clockmaker, translator, astronomer, politician, curator, and always a scholar and scientist. Public positions held by him included: city surveyor of Philadelphia, engineer of public works during the Revolution, trustee of the state's Loan Office, member of the Pennsylvania Assembly, State Treasurer, and the first director of the first mint in the United States.

In the field of science and philosophy, Rittenhouse held high and important honors and positions: librarian, curator, and, finally, President of the American Philosophical Society; fellow of the American Academy of Arts and Sciences, Boston; Professor of Astronomy and Vice-Provost, College of Philadelphia; fellow of the Royal Society of London; and trustee of the University of Pennsylvania. He was given the honorary degree of Master of Arts by the College of Philadelphia and by the College of New Jersey, the latter institution also granting him the degree of Doctor of Laws.

Among his constructions were an orrery (planetarium), a "metalic thermometer," an observatory, and numerous astronomical instruments.

Rittenhouse made an English translation of Gotthold Ephraim Lessing's play *Miss Sarah Sampson, or the Unhappy Heiress.* The translation was published by Charles Cist as *Miss Lucy Sampson, or the Unhappy Heiress,* and was attributed to "A Citizen of Philadelphia."

We are told by the author that in astronomy, mathematics, and physics Rittenhouse's grasp of fundamentals was complete, something which Benjamin Franklin could not and did not claim. Of this deficiency the latter was acutely aware, and so he could write to the lieutenant-governor of New York, Cadwal-

lader Colden, when Colden disputed his theory that ships must necessarily sail more slowly to westward than to eastward because of the rotation of the earth: "I ought to study the sciences I dabble in before I presume to set pen to paper." And so Franklin deferred to Rittenhouse's sounder knowledge in astronomy and mathematics. When he acquired a telescope equipped with a micrometer, he appealed to Rittenhouse for an explanation of the accessory. To men who valued astronomy and mathematical research and recognized the indispensability of scientific method, Rittenhouse, says Ford, had no peer in America. In his *Notes on Virginia* in 1781, Jefferson wrote:

> We have supposed Mr. Rittenhouse second to no astronomer living; that in genius he must be first, because he is self-taught. As an artist, he has exhibited as great proof of mechanical genius as the world has ever produced. He has not, indeed, made a world, but he has by imitation approached nearer its Maker than any man from the Creation to this day.

Jefferson, as other instances indicate, was given to the use of the most superlative language to describe the traits of those whom he liked and, in like manner, to attack those whom he did not like. As Ford points out, this and other encomiums quoted were, of course, too sweeping since in England, France, and Germany there were a number of astronomers and scientists who outranked Rittenhouse; but the fact still remained, as the author states, that in America Rittenhouse stood alone.

Rittenhouse dabbled in theories about the plurality of worlds and their possible inhabitants, as did Thomas Paine, and expressed the hope that if Mars and Venus were inhabited, they could not be reached by "British thunder, impelled by thirst of gain"! He lashed out at tyrants and was an aggressive Whig at all times. When Franklin withdrew from the Pennsylvania Assembly, Rittenhouse was chosen as his successor. Jefferson chided him for mixing in politics and neglecting science.

That Rittenhouse was a true liberal, devoted to the cause of democracy and common men, is conclusively established by the fact that he incurred the undying enmity of John Adams, who at heart was a monarchist, determined on having a king and an aristocracy in America. Adams let loose a tirade of adjectives against Rittenhouse: "a good, simple, ignorant, well-meaning, Franklinian democrat, totally ignorant of the world as an anchorite, an honest dupe of the French Revolution," etc. Ford says: Adams' "own revolutionary ardor had cooled since 1776." No, it had not cooled for it never existed. Adams, it is true, favored independence but not revolution. He was opposed to the transfer of the divine right of kings to the divine right of the people. He opposed democracy and favored a monarchy.

Rittenhouse was the "Mint-Builder" of our country. He purchased the ground for the first mint—the very first real estate ever owned by the United States—built the building and equipped it, and was the first director of the mint.

Rittenhouse joined no church. His mother was a Quaker, his father, a Mennonite. His first wife died, and he married again. Both his wives were Quakers, both were married "out of the meeting," and both were "disciplined" for their "indiscretions." Because of his belief in the plurality of worlds, in their probable inhabitation, and in Newtonianism, Rittenhouse was tagged an "atheist." In his address to the American Philosophical Society in 1775, he said:

> The doctrine of the plurality of worlds is inseparable from the religion. . . . Nothing can better demonstrate the immediate presence of the Deity in every part of space, whether vacant or occupied by matter, than astronomy does. It was from an astronomer St. Paul quoted that exalted expression, so often since

repeated, "In God we live, and move, and have our being!" . . . I would sooner give up my interest in a future state than be divested of humanity; I mean that good-will I have to the species, although one half of them are said to be fools and the other half knaves. Indeed I am firmly persuaded that we are not at the disposal of a Being who has the least tincture of ill—or requires any in us.

His aloofness toward the church, Ford suggests, was like that of many Colonial thinkers, who accepted tacitly the tenets of Deism, "a view strengthened by the fact that he found congenial the Unitarian views of Jefferson and Dr. Joseph Priestley."

The University of Pennsylvania Press is doing a much-needed work in presenting "Pennsylvania Lives" of men who contributed vitally to the revolutionary thought-structure of our way of living. Mr. Ford has done a splendid service in extending another great Pennsylvanian beyond the state and beyond the nation, to become a world influence. Only in the ideas of common people, whose hearts and minds live in the realm of things universal, and away from the narrowness of individualism and nationalism is there hope of individual, national, and world survival.

R. C. ROPER

NEW YORK, N. Y.

MATHEMATICS MADE EASY?

The Common Sense of the Exact Sciences. William Kingdon Clifford. Edited, with a preface, by Karl Pearson. Newly edited, with an introduction, by James R. Newman. Preface by Bertrand Russell. lxvi + 249 pp. Illus. $4.00. Alfred A. Knopf. New York. 1946.

WITH nearly all more or less educated people, even arithmetic is a "bookish" subject, let alone algebra or geometry. Before we have the time and the opportunity to learn about these matters from actual experience—by "common sense"—the school pounces upon us with its textbooks. Further learning becomes clothed in all the paraphernalia of the erudite, with all its forbidding symbolisms, its learned vocabulary, and all its—goodness-knows-by-whom—revealed truths and rules.

It is therefore very refreshing to find someone who reminds us that in spite of all these learned trappings the basic rules of arithmetic and algebra are nothing more and nothing else *but* "common sense"; especially if this is done in as simple and as convincing a manner as in the book under review.

The study of space begins with the assertion: "Geometry is a physical science." By now we have grown quite accustomed to this point of view. But in the eighties of the last century, when the "ideal world of geometry" was still excellent currency, this was a bold statement. Clifford develops the basic notions of geometry, using solids as his point of departure. He anticipated some of the ideas which later became popular owing to the writings of Henri Poincaré.

The author does not limit the scope of his discussion to the mathematical equipment that is the common possession of most readers. He tries to add to this store of knowledge and to widen the mathematical horizon of those who are willing to make the effort of following him in his entertaining presentation.

The book is printed in large type, with pleasing illustrations, and has a very attractive binding. It would be a fitting addition to any library and should be on the shelves of both our public and our school libraries.

It would seem, however, that a less ornate and much cheaper edition of this book would be desirable also, an edition that could readily find its way into the pocket of a high school student, into the rooms of a college dormitory, into the hands of those whose intellectual hunger is far ahead of their affluence.

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COMMENTS AND CRITICISMS

Coghlan and Gerard

The June issue of SM features two contributions so noteworthy that the writer feels constrained to comment briefly on them from the standpoint of a layman sympathetic to scientists at a time when scientific achievements and purposes are becoming the topic of conversation of most civilians.

First of all, allow me to congratulate you on that most timely article by Ralph Coghlan, "The Need for Science Writing in the Press." Anyone who has had the patience to wade through the various articles by philosophers, psychologists, and psychiatrists that have broken out in recent numbers of SM, purporting to speak for the great body of science about the controversial subjects of the day, must realize that such men have lost the power to express their ideas in the language of the common man whom they wish to reach. Indeed, the P–P–P division, if they really are qualified to act as mouthpieces for the inarticulate laboratory workers who are responsible for modern wizardry, must be hard put to it to understand one another's theories. Certainly, a convention of P–P–P's would be the last word in boredom to the average citizen, especially if international relations were discussed in terms of organic wholes and discrete integral processes of the hypotenuse.

Of course, nobody expects a philosopher to employ the gracious phrases of a Robert Louis Stevenson, nor that he be endowed by nature with the incisive wit of a Will Rogers or a Mark Twain, nor that he stir men's souls with the marvelous oratory of a Winston Churchill. Yet the fact remains that many of our greatest men have dealt with their fellow humans in the language of the common man; so much so, indeed, that one is inclined to ascribe small stature to him who hides his thoughts behind a screen of equivocal verbiage. Mr. Coghlan has expressed the belief that many wise scientists are more than anxious to bring the implications of scientific research to the public in terms that the latter can understand. He might have mentioned the fact that Professor Harold C. Urey recently appeared as one of the speakers at a Town Meeting of the Air on the radio. That he answered the questions of the audience in language that all could comprehend and made some excellent points to elucidate the position of science in present world politics argues well for the ability of truly great scientists to come out from behind the screen and talk as the rest of us do.

Many years ago the writer had occasion to translate a number of technical articles from American scientific journals into Spanish for the newspapers of a certain South American country. How well he would have succeeded with some of the more recent contributions of American philosophers is, of course, quite debatable. These men now argue that life is so much more complex than it was that a new technique of expression is necessary to put over one's ideas. Be that as it may, it would seem that many seem to forget the fact of overspecialization, a process which entails coinage of trade terms such as those employed by psychoanalysts and others who wish to impress the ailing public and thus command higher fees. Since it now seems of such importance to let the rest of the world know what our scientists are thinking, and since the bulk of the information will suffer by translation at best, how unfortunate that they do not even speak the language of their own people.

The other article to which the writer refers is the masterful essay of Dr. R. W. Gerard on "The Biological Basis of Imagination." Here again one must be up on his toes to understand some of the terms employed. But Dr. Gerard goes to some pains to make the scientific verbiage comprehensible, and the effort to keep abreast of his reasoning is well repaid. Here is a man who must be a prodigious worker. We feel that he must be deeply interested in his work and that he has helped to push back the frontiers of that most interesting of all sciences, our knowledge of ourselves, our own innermost and personal selves. Your correspondent believes this is an inspired article, one in which Dr. Gerard expresses himself in elegant English approaching the lyric qualities of a poem. Such writing can come only from a man who is sure of his ground, one who has tested and retested his findings to a point that the pieces fit together into a whole, which, while still far from perfect, is sufficiently intelligible to give his readers something of the thrill which must be his as he goes ever deeper into this absorbing subject. Such an essay goes far toward re-establishing one's faith in the ultimate emergence of lasting truth through unremitting labor rather than through the empty theorizing that so many philosophical writers affect in lieu of honest effort. Congratulations, Dr. Gerard, and many thanks from at least one of your readers.—P. R. GLEASON.

CORRECTION: The writer of the letter on pp. 159–160, August SM, is Joshua L. Baily, Jr., San Diego, Calif.—Ed.

THE BROWNSTONE TOWER

August. "A day of torpor in the sullen heat of Summer's passion" wrote James Whitcomb Riley. Everyone should be taking his annual siesta by the old swimming hole or wherever waves lap on the beach or mountain streams murmur among the rocks. Why should anyone read the SM in August when he might read Riley or refuse to do more than contemplate the sky and sea and shadows? But Dr. H. M. Davis of Pennsylvania State College writes that his nonmember colleagues are wearing out his August issue. Why? Because Bruce S. Old in that issue poked a little mathematical fun at wartime committees, boards, and panels. It goes to show that if we must have an August issue it is well to put some levity in it. The times are so out of joint that a little satire should be acceptable in any issue. Thus we now present "The Last Canute" by Garrett Hardin, as an antidote to threatened "suffocation by our own intellectual excreta."

In lieu of a vacation the editor intends to keep on rambling through this page. It is really too hot to view with alarm or try to reform anything. S. 1850 died quietly last week in a committee of the House. Dr. Howard A. Meyerhoff, who did his best to prevent the abortion, performed the autopsy in *Science*. It seems that scientists went fishing or something when they should have been at the bedside. "Never mind," says the Navy, "we'll take care of fundamental research. "We'll not only protect the nation but build it up through research." This was the impression we obtained from Captain R. D. Conrad, Director of the Planning Division of the Navy's Office of Research and Inventions, the only Government agency now providing for the active and comprehensive support of fundamental research. The Captain and his men were cordial and enthusiastic. It was obvious that they have a Mission to perform, and there is no doubt that their program will advance science as well as the Navy. With the best naval and civilian advice they could obtain they have already approved and are supporting scores of research projects in colleges and universities throughout the country. Superconductivity, underwater sound, crystal strength, supersonic aerodynamics, propulsion, electronics, nuclear physics, mathematical computation, medicine, and psychology are some of the subjects of research discussed by Captain Conrad in a recent address on the Navy in research. We hope that some of these developments will be described in the SM, since most of the projects are free from security classification. The Navy's program of research is all to the good, for if war comes again, it will not be caused by increase in physical and biological knowledge but by social and moral ineptitude.

We like Captain Conrad and we wish him great success in his cooperation with civilian scientists. But our enthusiasm for his program is somewhat tempered by "the Mathematics of Committees, Boards, and Panels." To be sure, the Navy is not farming out projects conceived in a smoke-filled room, but it would be only human for some professors to shape their proposals for research to fit the supposed needs of the Navy as indicated by the titles of projects already under way. Thus the Navy may unintentionally restrict freedom of research. For this reason we hope that research men will never be entirely dependent for their bread and butter on appropriations from military or civilian Government agencies, or on grants from industry for that matter. The urge to make observations or experiments that would not appeal to any purse must not be completely repressed by Men of Measured Merriment.

In spite of the heat we seem to have forgotten our rambling vacation. "And Day sinks into slumber, cool and sweet, within the arms of Night."

F. L. CAMPBELL